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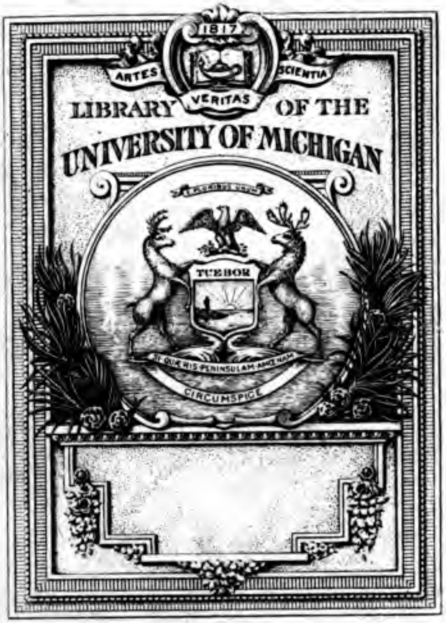
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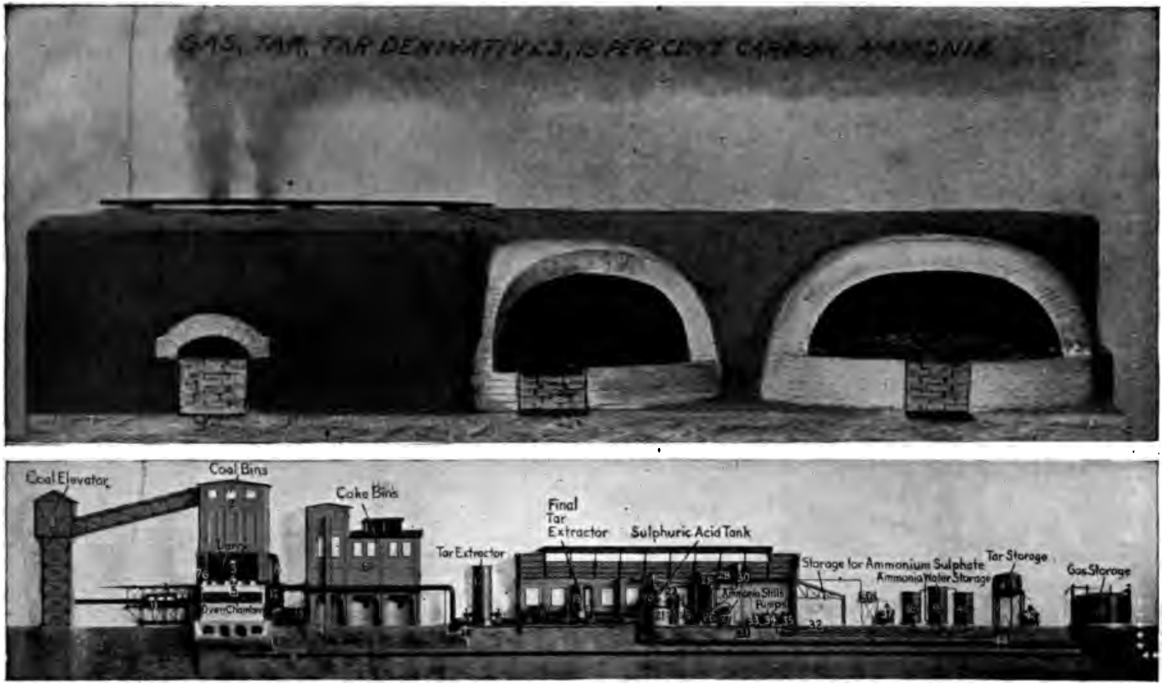

The old and the new: Bee-hive coke oven and modern by-product coke plant.
(From models in the Division of Mineral Technology, U. S. National Museum.)

AMERICA'S POWER RESOURCES

THE ECONOMIC SIGNIFICANCE OF COAL, OIL AND WATER-POWER

BY

CHESTER G. GILBERT

AND

JOSEPH E POGUE

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TO

LYDIA AVERY COONLEY WARD

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PREFACE

This book is an attempt to interpret the special, though generally unrecognized, importance attaching to the energy resources—coal, oil, natural gas, and water-power; and to point to the shortcomings in the way they are handled, to which a considerable measure of our current economic difficulties is traceable. The attempt is also made to outline the changes in energy administration that are bound to come into play, if due social and industrial progress is to be attained, and to indicate the avenues of advance to which constructive efforts need to be applied.

The material presented is largely the result of investigations carried on by the authors in the Smithsonian Institution, in the Fuel Administration, and in a somewhat diversified engineering practice, and brought out from time to time as special papers, emanating mostly from the Division of Mineral Technology, United States National Museum. These special contributions have attracted such notice that it seems desirable to weld the results into this unified and less technical form for wider and more popular presentation. The authors owe a debt of sincere appreciation to the organization that made the work possible and to innumerable individuals who contributed suggestions and information.

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AMERICA'S
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CHAPTER I

HUMAN LABOR AND MECHANICAL WORK

IN the struggle for existence man has advanced to his present position through a facility for turning the forces of nature to account. In modern life the outstanding expression of this proficiency is industrialism—the coöperative employment of mechanical power for useful work; the delegation of service to machines energized by coal, oil, gas, and water-power; the organized gaining of a livelihood.

The operation of industrialism calls for a large supply of human labor to supplement and direct the work of machines. Unfortunately, much of the work performed by human effort is still of a low order, requiring little intelligence and commanding a small compensation. The necessity that this "dirty work" of industry be done imposes a disagreeable burden upon a large class of society and constitutes the leading problem of the day, popularly and superficially designated the problem of capital and labor. The fundamental question before society is how to get the distasteful work of existence accomplished.

The answer to this question was easy in the earlier stages of social development, through the enslavement of a laboring class which was forced to do the undesirable work. In modern industrial nations the problem has been met and a supply of unskilled labor maintained either by repressive methods on the part of the governing classes, which made it difficult for the underlying masses to advance to higher types of work or at least kept them submissive to their lot, or else by importations of ignorant labor from foreign sources of supply. The first has been a method identified with autocratic forms of government; the second has been the expedient of democracy.

In its past history, the United States, the foremost proponent of democracy and the leading industrial nation, has based its growth upon the existence of repressive forms of government elsewhere. Up to the war, roughly speaking, three quarters of our unskilled mine, mill, factory, and construction labor were bred abroad in the environment of autocracy. For years American industry prospered because of the existence of ignorant and suppressed European peoples who came to our shores to gain relief from political and social pressure. Such has been autocracy's contribution to the industrialism of democracy.

Autocracy holds to ignorance, to subservience, to social repression; while democracy makes for education, for freedom of opportunity, for social consciousness. In receiving these peoples in our school of democracy, and in educating them to a fitness and a desire for better things, we have relied upon a continued flow of immigration to sustain the social advance brought about through the assimilating of the older increments. In this way we have met the requirements of industrialism without doing apparent violence to the principles of democracy. By virtue of the existence of autocracy abroad, we were able to live the inconsistency of combining an economic need for ignorance with a social focus upon its effacement.

The outcome of the war has profoundly affected this situation. We entered the war for the express purpose of asserting social and economic changes of a far-reaching order. Among the changes accomplished was the upset of conditions that furnished our unskilled labor. Ours has been the position of a man at work upon a tree, sawing off the limb against which his ladder rests,—all well and good until the job is done. The job was finished in late 1918; since then we have been in the air. The question is, where are we going to land? Will social readjustments in Europe create renewed support for our industrial labor supply? Are we to pass on and find new sources of supply in the overpopulation of Asia? Or must we come down to earth and reëstablish our support on a new basis?

The European peoples from whom we have been drawing our industrial labor supply have not found their social and economic status so greatly bettered as a direct outcome of the war that the United States has lost its power of attraction. But the question is not one of quantity alone; it involves quality quite as much as quantity. How well content, how amenable, how tolerant will the immigrant class of the future be with regard to the place reserved to it in the past? In this connection the social changes wrought in the furnace of war during recent years are of the utmost practical significance.

We in America have watched the development of social consciousness abroad as from a grand stand. We have watched it burst the fetters of Russian absolutism, and in the sudden sense of unaccustomed freedom start a wholly new social experiment whose outcome is still in question; we have watched it eat away the iron ring of Prussianism, even as it was being battered to pieces from without; we have watched it assert the rights of a dozen subject nationalities; more recently and more significantly still, we have seen it soberly and constructively at work on the enormous task of remodeling the economic imperialism of England.

Absorbed in watching the dramatic aspects of this social revolution in Europe, we are prone to misinterpret its bearing upon the economic welfare of the United States. We are disposed to disregard the fact that, aside from the Negro, our unskilled labor is well-nigh wholly produced as a direct result of European conditions; we are inclined to overlook to what extent Russian absolutism, Prussianism, suppressed nationalism, and the lesser evils of Europe's past have contributed to the solution of our own problems. We forget the degree to which we have been economically dependent upon the darkness of European political institutions.

We in the United States would do well to give serious thought to the bearing which the social changes in Europe will have upon our American industrialism. We should recall that our labor supply is drawn from the areas most deeply affected,—from Russia, Poland, Hungary, and the Balkans on the one hand; and from Italy on the other. The social and political changes in eastern Europe have been revolutionary; future immigrants from this region may be expected to bring a social consciousness at radical variance with the old temper. The alteration in the social status of Italy may turn out to be scarcely less profound; the Italian peninsula harbors a smoldering volcano, socially no less than geologically. All this is not a passing situation. The changes that have taken place in Europe strike deep. Generation upon generation of struggle against ignorance and suppression does not register with temporary effect. Public opinion may change overnight by a process of substitution, but public consciousness, social consciousness, is a matter of evolutionary development and does not reverse itself.

Conditions abroad are renewing our industrial labor supply, but in proportion as developments take this course they will still further foster the social unrest and extremism born of repression in the past, a very dangerous source of reliance. And we are tending still further to restrict the inflow of foreign labor by the establishment of rigorous immigration laws, and to change the character of those arriving by vigorous campaigns of Americanization. If altered conditions and our own efforts succeed in pruning down the contributions from abroad, will our Americanized labor be content to descend the social scale and fill the position at the bottom hitherto left to the non-Americanized immigrant? The question needs no answer. It has been suggested, and the suggestion has even found lodgment in a government publication, that the situation might be relieved by opening our doors to a certain number of Asiatics, presumably on something of a parity with the social status of the Negro in the South, but such a step is too impractical for serious consideration.

While we have been absorbed in watching the progress of events abroad, we have been rounding the turn where we must face the lack of social and economic adjustment at home. Both here and abroad the war condensed within the lapse of five years the normal social advance of fifty, without bringing corresponding progress in economic development. This sudden advance in democracy has left industry far behind. The true problem facing industry is how to catch up, not how to go back to the earlier status.

The industrial situation, in fine, is affected by a steadily increasing pressure, arising from the fact that social consciousness has been developing more rapidly than the means for satisfying it. This pressure must have relief, or the social structure will fail. Adequate relief can come only through increased use and efficiency in respect to mechanical means for multiplying production. Such has been the avenue of relief throughout all history, from the human treadmill to the modern quantity-production factory. The progress of democracy is measurable in terms of the advancing use of mechanical work in the place of human labor.

In its application to the United States the problem is not a new one, though never before has it presented itself in so accentuated a form. All along, due to our democratic principles, we have felt the pressure of a steadily advancing wage scale. And all along we have solved this issue in the only way it can be solved,—by increasing the effectiveness of the human factor in production. Industry is familiar with the necessity of getting the work done with the least expenditure of labor.

The whole development of industrial concentration and quantity production, so typically American, are but illustrations of our economic adjustments to an advancing social status. Already these adjustments have made this country the greatest consumer of power in the world. Five years ago industry could not afford to employ the working methods of fifty years back. Neither can the reconstructed industrialism of to-morrow afford to employ labor with the pre-war effectiveness of yesterday. On the contrary, there must be a tremendous conserving development in eliminating waste effort and furthering the employment of mechanical means, through coördination of activities and more intelligent use of energy.

CHAPTER II

THE FOUNDATIONS OF INDUSTRIALISM

MODERN civilization is dependent upon the accomplishment of more work than human labor is capable of performing. This multiplication of human effort is brought about through the utilization of the energy stored up in natural resources,—coal, oil, gas, and water-power.

The energy derived from natural resources has come into use in three media of expression,—liquid, gaseous, and non-substantial,—typified in hydraulic power, steam-power, and electric power. These successive steps in energy usage represent progressive stages in facility of employment and indicate an evolutionary trend in the growth of industry for which they are responsible. Thus the use of hydraulic power, epitomized in the water-wheel, marks the period of individualism which prevailed the world over until the eighteenth century and still holds in all but the so-called civilized nations. Subsequently the application of steam-power instituted a change so profound as to be called the Industrial Revolution, and colored the whole face of modern civilization during a stretch of time to the present, which may be termed the formative period of industrialism. This period is also characterized by further elaborations in the use of energy in gaseous form, as illustrated by compressed air and especially by the internal-combustion engine which utilizes directly the expansive force of the gaseous products of combustion. Finally, the introduction of electric power brings forward a third major advance in power usage, offering to the maturing aspects of industrialism a special service needed to carry forward its complex and constantly enlarging activities. Just as steam-power opened up the coal-fields of the world and freed the employment of power from the geographic restrictions inherent in the use of the pressure of falling water, so electricity reinstates water-power on terms of equality with coal, offers the means for the transmission of energy devoid of bulk, and affords a readiness of subdivision and ease of application that considerably enlarge its range of service.[1]

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[1] The advantages of electricity arise from the fact that this strange and even mysterious manifestation of energy is virtually

The development of energy thus far has focused upon the mechanical means for applying energy to an ever widening range of duties, with only incidental regard to the supply of energy itself. The utmost in engineering and financial effort has gone into improving the various types of engines employed in generating energy, and into elaborating the machines and mechanical devices engaged in converting the energy into service; but the energy resources themselves and the means for handling the energy materials have been left to a haphazard development without plan or order. In consequence, the energy situation is characterized by a striking contrast in which the field of energy application is marked by progress and technical proficiency, while the activities that go before the actual utilization of the energy are unorganized, wasteful, and extremely incompetent as to both technical and economic efficiency.

The energy resources of principal importance, as already noted, are coal, petroleum, natural gas, and water-power. Because of the diverging and rapidly developing growth in the utilization of

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energy itself,—not energy locked up in a material condition and subject to the laws and limitations of matter, but energy, the capacity to do work, freed from substantial form.

energy, these ultimate sources of energy supply, especially during the past ten years, have come to be drawn upon to a truly amazing degree. Thus, in the United States alone, three-quarters of a billion tons of coal, one-half of a billion barrels of petroleum, seven hundred billion cubic feet of natural gas, and ten million horse-power of hydro-electricity represent the annual measure of the energy demand; over a third of the freight of the country is coal; the smoke and grime of cities are unburnt fuel; more than a million men are engaged in the mining of coal and oil alone.

The United States is more amply endowed in respect to energy resources than any other nation in the world, and makes a larger use of these materials than is enjoyed elsewhere. In the production of coal and oil this country takes the lead, turning out nearly one-half the world's quota of coal and over two-thirds of the total output of petroleum. Natural gas is produced in large quantities in no other country. Water-power, alone, is drawn upon on a relatively meager scale, compared with its possibilities. An inventory of the energy situation in the United States, reduced to a per-capita basis for ready visualization, stands as follows:

ENERGY RESOURCES OF THE UNITED STATES CALCULATED TO A PER-CAPITA BASIS[a]

	PRODUCED 1920	USED TO DATE	UNUSED
Coal	6.5 tons	141 tons	35,000 tons
Petroleum	4.4 barrels	54 barrels	59 barrels
Natural Gas	0.3 ton coal[b]	([c])	([d])
Water-power	0.4 ton coal[e]	....	3.6–12 tons[e] coal per year

[a] Calculations are made on the basis of a population of 100,000,000 and the figures are given in round numbers. Data on coal and petroleum are from publications of the United States Geological Survey.

[b] Rough estimate of coal equivalent; 753,000,000 M cubic feet of natural gas was consumed in 1916

[c] Natural gas has been used so wastefully in the United States that the conventional coal equivalent of the total amount used to date would give a misleading idea of the service rendered.

[d] Reserve not open to close estimate, but a large fraction of the original supply is already exhausted

[e] Rough estimate of coal equivalent.

The table above goes to show the tremendous extent to which the United States is dependent upon the energy obtained from its material resources. The actual figures are so staggering in their magnitudes that a further comparison is necessary if their full significance is to be grasped. The amount of work which an average man can perform in a day is a convenient and familiar unit. It would require the labor of three billion hard-working slaves to accomplish the work done annually in the United States by our energy resources. This estimate is a rough approximation merely, based upon an assumed power utilization of 150,000,000 horse-power and the equivalence of 20 man-power for 1 horse-power. The use of energy materials gives to each man, woman, and child in this country the equivalent of thirty servants. Our type of civilization arises from this organized use of inanimate energy.

In contrasting the rôle of energy in Great Britain with that in ancient Greece, James Fairgrieve writes:

> The power of Greece, whereby she achieved such great things in all directions of human progress, was largely based on the work done by the servile class. On the average each Greek freeman, each Greek family, had five helots whom we think of not at all when we speak of the Greeks, and yet these were the men who supplied a great part of the Greek energy. In Britain, we may say, each family has more than 20 helots to supply energy, requiring no food and feeling nothing of the wear and tear and hopelessness of a servile life.

This substitution of resource energy for human energy, of mechanical work for human labor, is the outstanding feature of the modern industrial order. It is a social and economic factor of the most profound significance. Its full capacity for social advance has not yet been realized,—for the reason, perhaps, that the world has been too busy developing this potent force to pay adequate attention to all that it might accomplish.

The preponderant use of energy in the United States is due to a blend of reasons. The size of the country, its great wealth in raw materials, the dearth of native labor, and the democratic theory under which the country has been administered have all contributed to making us more dependent upon energy than other nations. A rapid material development, such as America has had, could have come about in no other manner than through an unparalleled utilization of resource energy and machinery. With freedom of opportunity, unrivaled resources, and an inherent mechanical ingenuity, American enterprise has followed the line of natural development, and built an industrialism that for sheer magnitude of input and output has no counterpart. In support of an industrialism of such proportions we have drawn with accelerating weight upon our energy resources until the annual drafts have reached their present imposing size. But in our attention to the superstructure, we have neglected the character of the foundation, and the energy situation in the United States has little but its great size to commend it; and even that is a source of grave weakness. American industrialism is reared upon a loosely jointed base which must soon come in for reconstruction, lest the whole structure topple.

As the United States is already dependent to an unprecedented degree upon her energy resources, and the events of the immediate future will call for a very significant advance in this dependence, we should look with particular care for defects in the energy situation. We cannot build safely beyond the strength of the foundation; and a cursory glance at the base of our industrial structure is far from reassuring that all is in order there. We have been prone to rest content that our industrial foundations were large in size, without due regard to the fact that strength lies not alone in bulk but in articulation as well; indeed, size in this instance represents a fault, and instead of priding ourselves upon inordinate increases in the production of energy materials, we shall soon come to see that this rapid expansion is the result of a forced stimulation in a wrong direction, and is not a sound and substantial growth. The time will soon come when we shall cease to boast that we produced fifty million tons of coal more this year than we turned out last year, without reference to the way the coal was mined or the manner in which it was handled and used. Considerations of efficiency will take precedence of magnitude.

It is notorious, of course, that in rapidly developing our resources in coal, oil, and natural gas, we have been exceedingly wasteful; we have sacrificed an unduly high percentage of these valuable materials in bringing into use the portions recovered. For every ton of coal produced, our methods of mining have placed a second ton beyond recovery; for every thousand feet of natural gas turned out, a similar quantity has escaped; and for every barrel of petroleum that has seen useful service, several barrels have been wasted. These losses are inherent in the excessively competitive methods of production followed in this country and have caused no great concern, as it has been generally felt that the unmined supplies of the materials were so vast that distant generations alone would feel the loss. Recent inventories of the unused portions of these resources, however, go to show that such is not the case,— that our best and most convenient coals will be depleted in a few decades, that approximately half of our petroleum is already used up, and over half of our natural gas is gone. In short, the wastes so prevalent in this field are of direct concern to our citizens to-day.

In addition, the mere bulk of energy materials that must be handled has become so great that a critical problem in transportation is created. Coal alone constitutes more than a third of the freight hauled by the railroads of the United States. Coupled with the high standard of living, which calls for an extensive movement of commodities, and the vast extent of territory to be served, the necessity for hauling such an enormous tonnage of coal imposes a burden upon the transportation system of the country that is causing all manner of difficulties. Especially is this true in periods of industrial expansion, when the railways find themselves called upon to haul for each unit of advance in industrial output a threefold increment in coal, raw materials, and finished products; and as a railway by nature is less flexible than an industrial plant, a transportation congestion or a breakdown is bound to occur on every such occasion. Thus, so long as coal and the non-energy-producing materials share the same channels of movement, the system will clog at the very time a greater flow is needed; a coal shortage results and not only must industry go short-handed, but the homes of the country must face a fuel shortage. The transportation tie-up and coal shortage during the winter of 1917–18 is a notorious example of the failure of present methods. Industrialism has outgrown our present inefficient manner of handling the energy contained in coal and rapid changes are due to come as the system is found increasingly incompetent to sustain the forward march of industrial growth.

In addition to the premature depletion of our richest and most favorably located supplies of energy materials, and the extent to which our present administration of coal is aggravating the problem of transportation, our current utilization of the energy materials is for the most part inefficient in the extreme. The result is not only an energy cost much greater than need be, but—what is more grievous, since we are adjusted and prosperous on the present scale—a prospective acceleration of energy costs such as may be expected, if unrestricted, largely to nullify the advantage of lavish endowment in energy wealth.

While the energy resources are used primarily for the generation of motive power, the situation is complicated by a range of lesser uses to which a considerable part of the energy is applied, and by the commodity values and commodity possibilities contained in the energy materials, particularly in coal and oil. A clear comprehension of these circumstances is requisite to an understanding of the attainments and shortcomings in this field, and for this purpose the whole matter may be simplified and tabulated in a rough, generalized form, as shown on page 24.

Thus, each energy material is used for the generation of power, the production of heat, the furnishing of light, the accomplishment of chemical work, and the manufacture of important commodities. Although these applications are largely complementary, it has come about that the various demands are filled for the most part as independent units, without reference to the fact that the same original quantity of material may be made to serve several functions as well as a single end. Accordingly, one portion of our coal output is devoted to power generation, another to the production of domestic heat, a third to the manufacture of coke, a fourth to the making of city gas; one part of the petroleum supply is consumed in the crude or semi-crude condition as fuel, another portion is partly refined, still another fraction is completely refined, and so on. In general, the energy material is applied to the immediate pur-

THE ENERGY MATERIALS AND THEIR USES.

	ENERGY CONTENT (only small part extracted by present practice)			COMMODITY CONTENT (mostly unused at present)	
	POWER (about two thirds of total coal and oil used for generation of power)	HEAT (in part derived from power)	LIGHT (in part derived from power)	CHEMICAL WORK	CHEMICAL PRODUCTS
Coal....	Generation of steam. Generation of electricity. Manufacture of gas used in internal-combustion engines.	Domestic fuel (anthracite and bituminous coal). Gas for heating. Heat for industrial processes. Nearly one sixth of total coal used as domestic fuel.	Electricity made from coal. Gas made from coal.	Reducing action of carbon in metallurgical operations. Nearly one sixth of total coal is made into coke for iron production.	Ammonia, benzol, and tar extracted from about one twelfth of total bituminous coal. Used as such and starting-point for manufacture of fertilizers, drugs, dyes, chemicals, and other coal products
Petroleum..	Gasoline for motor use. Fuel oil and crude petroleum for steam-raising. Kerosene for motor use.	Kerosene for domestic heating. Heat for industrial processes.	Kerosene for lamps. Gas and electricity made from gas oil.	....	Lubricating oils, benzine, vaseline, asphalt, paraffin wax, etc.
Natural Gas...	Used in internal-combustion engines. Used for steam-raising.	Domestic heat. Industrial heat in glass-making, etc.	Gas-lighting.	....	Lampblack.
Water-power.	Generation of electricity.	Domestic heating by electricity. Electric furnaces for metallurgical and chemical work.	Electric lighting.	Electro-chemical manufacture. Electro-metallurgical processes.	Water.

pose at hand, with no reference to any other consideration.

As a consequence of this uncoördinated use, a vast excess of coal and oil is consumed above the intrinsic requirements. Because, also, of the general neglect of the commodity values contained in the materials consumed merely for their energy content, a monetary loss running up to staggering figures is entailed, which should properly be recovered and turned to reducing the cost of energy. Correlated with this commodity loss are serious civic and economic problems, such as the smoke nuisance arising from the consumption of raw coal, which is responsible for inestimable destruction in social and material advance; and the shortage of domestic nitrogen needed for the manufacture of fertilizers and explosives, which is compensated by importation from unreliable foreign sources of supply.

While coal, oil, natural gas, and water-power are to a great measure interchangeable, each possesses certain individual and highly important specializations. Without regard to their distinctions, these four sources of energy have been exploited as competitors, the cheapest and most convenient one in any given instance being drawn upon. The lavish endowment of this country in all four respects has supported and encouraged this competition up to the present. Thus the limited reserve of oil is being used in place of coal and water-power; coal is doing its own duty and that of water-power as well; natural gas, the ideal fuel for homes, is in large part devoted to the crudest of industrial applications; water-power is largely neglected. For the sake of expediency, our most precious assets are being squandered at an unbelievable rate. The very abundance of supplies has made it unnecessary to take thought or care in their behalf.

The entire energy situation, as it has developed without plan or forethought, is in an unsound condition. The whole structure is already seriously out of adjustment with the needs of the industrial system that rests upon it, and there are attendant faults that reach out and concern directly the entire body of society. The general shortcomings have already been reviewed; a summary of the specific defaults may be introduced as a tabulation of the main points at issue, which at the same time will serve to list the problems that the detailed matter to follow is designed to interpret. Thus:

	Production	Transportation	Utilization
Coal	Overproduction. Too many mines. No storage. Improper competition. Inappropriate leasing system. Inadequate application of technology.	Undue burden upon railways due to hauling energy in bulky form. No existing common-carrier system for coal-generated electricity.	Almost total waste of commodity values due to consumption of raw coal. Great loss of energy due to disorganized utilization and surplus production. Needless use in place of water-power.
Petroleum	Overproduction. Too many wells. Improper competition. Inadequate application of technology.	Satisfactory.	Waste of commodity values due to use of crude and semi-crude petroleum. Loss of energy due to forced overproduction. Needless use in place of coal and water-power.
Natural Gas	Same as for petroleum.	Satisfactory.	Loss of energy due to overproduction. Needless use in place of coal.
Water-power	Underdeveloped. Legal restrictions. Unsuitable financial restrictions of high money rates.	Satisfactory so far as developed.	Satisfactory so far as used.

In the face of wasteful and inefficient methods of energy administration, the United States is confronted with a situation that calls for a continued increase in energy consumption. Although a tremendous amount of energy is already being used, a greatly increased supply is needed to compensate for the rapid progress in the status of human energy and to sustain the expansion in industry required by an advancing standard of living at home and a substantial trade abroad.

A growth along the old lines will not suffice,—indeed, will not prove possible. We have already shoved the production of energy materials about as far, in point of sheer bulk, as is possible to go. There are limiting factors that will turn further advances from the channels of bulk increase into directions in which the focus will be upon coördination and efficiency. Up to the present, the energy situation has grown by mere accretion, with no adjustments looking to a diminution in the waste and lost motion involved; having great reserves of material resources at hand, we have followed the direction of least resistance and boldly drawn upon these supplies in increasing measure. We now face a transportation system incapable of accommodating industrial expansion and the requisite growth in coal production at the same time; an oil production which has reached its maximum; a natural-gas output that is on the decline; a water-power development that is stagnant. Yet the demand for an increased energy supply is not to be gainsaid. There can be but one way out,—a change in the development of the resources which will give a higher percentage of energy service from the materials brought into use.

The issue has a twofold aspect. Under present methods of dissociated, bulk production, we can neither secure an adequate supply of energy to meet the needs of the immediate future nor hold the price of energy down to levels at which it can be used to fulfil its proper functions. Without an abundant supply of energy we cannot have industrial progress; without a cheap supply social progress cannot be maintained. Put in another way,—there is a balance between the price of human energy and the price of material energy; the two cannot advance in like degree.

Economic progress requires ample energy; social progress, cheap energy. Our form of government professes social progress as its aim. Economic progress, it goes without saying, is necessary to sustain social progress. The events of the past five years have created a more sensitive social consciousness than formerly existed. The wide-spread and organized desire for social advance will exert a pressure upon industrialism that will affect its foundations, the energy resources, to the end that energy may exert its proper influence upon the advancement of industry and society alike.

These considerations, it is believed, are going to bring far-reaching changes in our methods of producing, handling, and using coal, oil, gas, water-power. Such changes will come as a matter of evolution, whether concerted attention is given this field or not, although progress may be facilitated by planning ahead. In the pages of this book our present attainments in this connection are reviewed, and consideration is given to the lines of progress which will be followed, if the whole system of industrialism—and that is to say, modern civilization—is not to go by default. The time is rapidly arriving when organized society will take stock in a scientific manner of the drift of affairs and by means of the forces at its command direct its destinies to a favorable consummation. The energy resources lie so concretely at the bottom of human welfare, that their cultivation cannot wisely be neglected. It is hoped that the present attempt to traverse the intricacies of this important field may throw a constructive light on the mechanics of democracy.

CHAPTER III

COAL, THE BASIS OF NATIONAL WELFARE[*]

COAL is the most important source of energy employed by our modern industrial civilization. In the United States alone the consumption of coal has grown to the enormous total of two thirds of a billion tons, nearly half of the entire output of the world. (See figure 1.) As it is difficult for the mind to grasp a quantity of such magnitude, a comparison made by Charles P. Steinmetz may be used to advantage:

> One of the great wonders of the world is the Chinese Wall, running across the country for hundreds of miles, by means of which China unsuccesfully tried to protect its northern frontier against invasion. Using the coal produced in one year as building material, we could with it build a wall like the Chinese Wall, all around the United States, following the Canadian and Mexican frontiers, the Atlantic, Gulf, and Pacific Coast, and with the chemical energy contained in the next year's coal production, we could lift this entire wall into space, 200 miles high. Or, with the coal produced in one year used

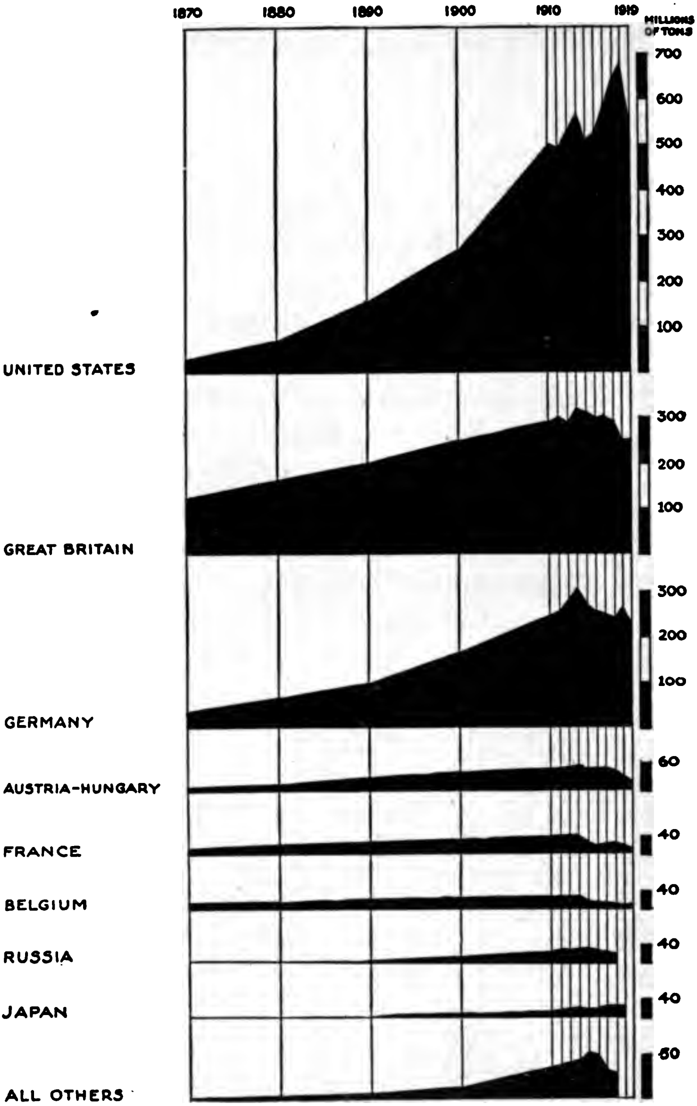


FIG. 1. Coal production of the principal industrial nations.

as building material, we could build 400 pyramids, larger than the largest pyramid of Egypt.

Coal is concentrated energy in material form. When burned, coal gives out a remarkable quantity of heat, which may be used as such or turned into mechanical or electrical energy for the performance of useful work. But coal is more than accumulated energy; it is a storehouse of valuable chemical products as well, awaiting merely proper treatment to yield valuable commodities with no sacrifice of its energy content. A striking commentary on the undeveloped status of coal is the fact that nearly all of the coal consumed in the world is burned in the raw state, with utter disregard of the products of potential value thereby destroyed. Smoke is the ever present evidence of this loss. The employment of raw coal marks the first era in the age of industrialism, sometimes called the age of coal, but more properly termed the raw-coal age.

Coal is composed predominantly of carbon, with variable proportions of volatile hydrocarbons, moisture, and ash, along with small percentages of nitrogen and sulphur. For practical purposes the composition of coal is determined by subjecting a sample to destructive distillation rather than to chemical analysis. Upon such treatment the coal yields up first its moisture, then the volatile components, leaving a mass of black carbon which may be burned to a final residue of ash. The volatile matter is responsible for the flame and smoke when coal is ordinarily consumed. The commercial value of coal depends upon the carbon and volatile matter present, moisture and ash being undesirable as detracting from the heating efficiency, and sulphur being deleterious because of its bad odor and corrosive effect. Nitrogen is a matter of indifference, except in coals subjected to by-product treatment, from which the nitrogen is recovered in the form of a valuable commodity.

There are three principal types of coal,—anthracite, or hard coal; bituminous, or soft coal; and lignite, or brown coal.

Anthracite is the purest form of coal and is composed almost entirely of carbon. It contains only a trifling quantity of volatile matter and burns without smoke. In consequence it is in strong demand for domestic heating, where cleanliness is especially desirable. Bituminous coal, unlike anthracite, carries considerable volatile matter; it burns with a long flame and produces dense black smoke. Its heating value is usually greater than that of anthracite, since the volatile components furnish a considerable quantity of available hydrogen which produces about four times as much heat as the same weight of carbon. Because of its heat-producing qualities and abundance, bituminous coal has become the mainstay of American transportation and industry. Lignite is a low-grade coal with nearly half its content represented by moisture. It has a low heating value and, as it crumbles to pieces upon storage, is difficult to handle. In consequence it is uneconomical to mine or transport wherever higher grade coals are available and has not yet become a factor in the industrial life of the country. Anthracite is fairly uniform in character, but there are many grades of bituminous coal and lignite.

Coal occurs in layers, interstratified with shale and sandstone, underlying extensive areas of the earth's surface. Its deposits range in thickness from seams too thin to be profitably extracted to beds as thick as fifty feet or more. In the United States coal-beds thinner than two feet are rarely worked, while the great majority of working beds are between five and ten feet in thickness. Coals vary in position from shallow beds outcropping on the slopes of ravines, to deep strata lying thousands of feet below the surface. In most localities coal is spread out in horizontal beds; but in many fields earth forces have thrown the deposits into undulations and even contortions, with resulting changes in the character of the coal and added difficulties in the way of mining. Anthracite, as might be expected from its compact character and freedom from volatile constituents, is found in steeply folded beds such as result from periods of great stress in geologic evolution.

Coal represents the altered remains of plants accumulated in untold quantities in ancient swamps, during periods of the geologic past when climatic conditions were favorable to an exuberant growth of vegetation. From a cosmic point of view, a coal-forming period is characterized by an atmosphere surcharged with carbon dioxide, as a result of world-wide volcanic eruptions; the upgrowth of a rank vegetation in nature's provision for removing the surplus gas. By virtue of the green coloring matter in plants, the heat of the sun is utilized in overcoming the tenacity with which carbon clings to oxygen; the carbon becomes fixed in the form of vegetation, the oxygen is given back to the atmosphere, and the radiant heat of the sun is caught and bound up with the solid matter of organic growth, ready to appear again when the accumulated carbon is subjected to the familiar chemical reaction of combustion. In certain periods of the geologic past, the natural fixation of carbon, which is to-day transpiring in more leisurely fashion, was a dominant process and gave rise to coal-forming periods on a scale for which we can to-day find no parallel. In Carboniferous time in particular did such conditions prevail and the bulk of the world's coal originated under the amazing circumstances of that distant era. Not only was an immense store of the sun's energy laid aside in material shape for the ultimate service of mankind, but part of the very oxygen essential to animal life was by the same means freed from its bondage to sustain the evolution of higher forms of life to their culmination in man.

The evidence in favor of a vegetal origin for coal is unmistakable. When the various ranks of coal are arranged in order according to their carbon content, it is found that they form an unbroken series from lignite through bituminous coal to anthracite, with all the intermediate varieties represented, indicating that the types of coal are but successive steps in the consolidation and alteration of a matted mass of plant remains. Even the preliminary stages in the formation of lignite are represented in the form of peat, which may be seen in process of development to-day; while in some localities a purer form of carbon than anthracite is found as an end product in the process. In the coal-beds themselves, and especially in the black shales accompanying the coal, the impressions of leaves and tree trunks are common and striking objects which furnish a direct means for determining the kind of vegetation and the climatic conditions that prevailed at the time the coal was formed. In recent years, also, the microscope has yielded additional evidence; for while peat and low-rank coals display their organic structure to the unaided eye, it is only upon magnification that the plant content of the high-carbon coals is clearly evidenced. The microscope, indeed, has demonstrated that even the most altered coals carry recognizable constituents in the form of spores, carbonized wood, and resins.

The coal-forming conditions of Carboniferous time can be inferred with some degree of accuracy from the record left in the rocks. Vast coastal swamps and tidal flats, of a size unknown to-day, were covered with a dense jungle of luxuriant vegetation. Great trees of soft and spongy wood reared their needle leaves high above the tangled summit of an evergreen forest whose dark recesses teemed with insect and reptilian life. No bright flowers or sweet odors tempered this primitive scene; nature seemed intent on sheer exuberance. The common plants were seedless and when periodically the vegetation unloosed its spores, the very atmosphere was thick with this greenish dust, which settled in the stagnant water in prodigal quantity. Under a moist and genial climate growth was rapid, and in an atmosphere deficient in oxygen, decay was slow; so through long ages the spore-dust and plant debris accumulated beneath the water covering of these steaming swamps, while periodic inundations brought in layers of mud and sand to seal up the beds of organic remains. Through a succession of such events beds of organic matter were formed and buried, ready to undergo the slow biochemical and physical changes incidental to the transformation of plant debris into the various types of coal that we use to-day. Through the agency of great earth movements these beds of carbon, with their associated sediments, came to be elevated into dry land and folded into mountain ranges, where they now form seams of coal, ready to yield themselves to the industry of men.

Coal underlies nearly five hundred thousand square miles of the United States and is widely distributed throughout the country. (See figure 2.) The bulk of the coal mined, however, comes

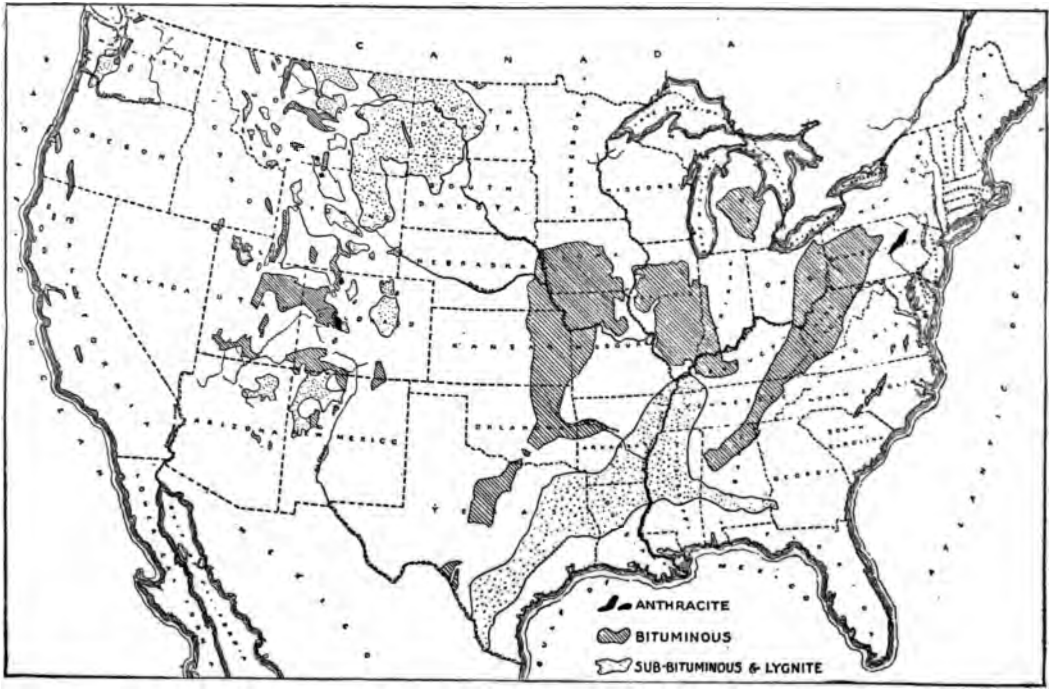


FIG. 2. The distribution of the coal fields of the United States.

from comparatively few regions, where proximity to industrial centers and quality of coal have led to extensive developments. Virtually all of the anthracite is obtained from an area of less than five hundred square miles in northeastern Pennsylvania. The most important of the bituminous-coal areas is the Appalachian field, extending from northern Pennsylvania to Alabama. This region is the greatest storehouse of high-grade coal in the world, and its rapid exploitation is largely responsible for the blast-furnaces, the great iron- and steel-mills, and the innumerable manufacturing enterprises of the Eastern States. From this field comes the highest-grade steaming coal in the country, especially prized for steamship and naval use, because it is nearly smokeless and requires less bunker space per unit of heat than other coals; also the most desirable coal for the manufacture of coke used in smelting iron is drawn from this field, especially from the neighborhood of Pittsburgh and Birmingham.

Next in importance to the Appalachian field is the vast bituminous area of the so-called interior province, which extends almost continuously from Michigan to Texas. While not equal in quality to the coal of the East, the coals of this region have been extensively mined, especially in Illinois, and support the transportation, industries, and much of the domestic heating of the Middle West. In the Great Plains and Rocky Mountains are coalfields of greater extent than all the more easterly fields combined, but the coals here are of lower grade than even those of the interior province; some high-grade bituminous coals are included, but the vast bulk of the deposits are lignite or sub-bituminous grades. (See figure 3.) Of the total production of coal in the United States up to the present, about a quarter has come from the anthracite fields of Pennsylvania, nearly a half from the Appalachian region, a fifth from the interior province, and barely a tenth from the great fields farther west.

In view of the paramount importance of coal, the position and the political control of the reserves of this substance are attracting considerable attention. The Twelfth International Geological Congress in 1913 prepared an elaborate summary of the coal resources of the world; and the United States Geological Survey has recently published a careful inventory of the unmined supply in this country. The results of these resource surveys are shown graphically in figure

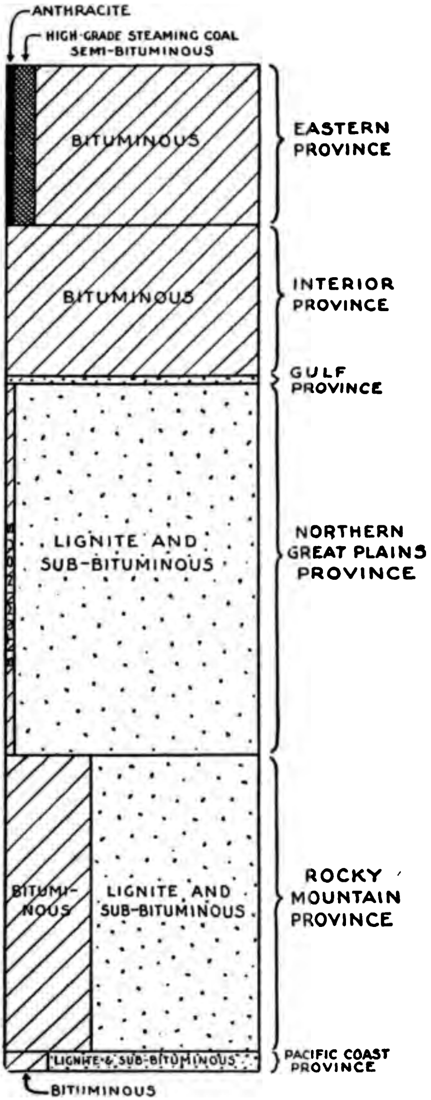
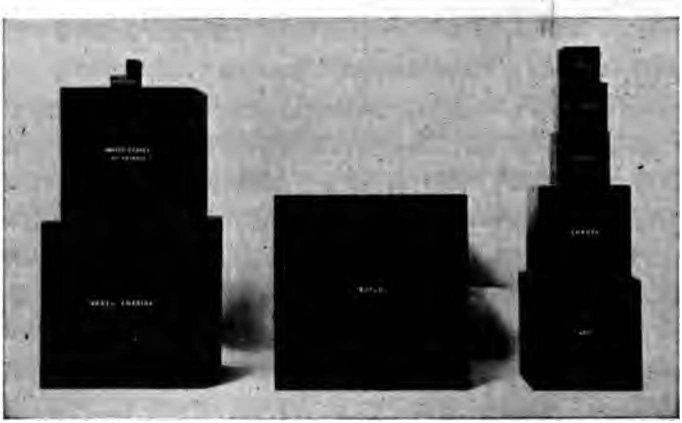


FIG. 3. The coal reserves of the United States according to grades and geographical distribution.

4, in which the dominant position of the United States is clearly seen. As the industrial and economic activity of a country is directly dependent upon the quantity of coal available, the geographical disposition of coal assumes unmistakable international significance for the immediate future.



(From a model in the Division of Mineral Technology, U. S. National Museum.)

FIG. 4. The coal resources of the United States compared with the rest of the world. The corner missing from the anthracite cube represents the approximate consumption to date; less than ½ of one per cent. of the bituminous supply is consumed.

Although the United States is rapidly approaching a billion tons as her annual coal requirement, and even now produces a quantity nearly as great as the combined output of the rest of the world, her reserves are so vast that, despite the quantity mined to date, less than one half of one per cent. has been touched. There has been much speculation as to the length of time the coal supply will last, but this is beside the point, as the coal mined to-day is the best in the country and, according to M. R. Campbell of the United States Geological Survey, "before long, perhaps within fifty years, much of the high-rank coal will be exhausted." The practical question, then, is not how long in an absolute sense our coal will last, but when shall we have to make changes in our industrial structure because the conveniently located and high-grade coals, upon which concentrations of industry and specialized uses are dependent, are beginning to run short? That time is closer at hand than is generally realized and is a consideration which demands the fullest utilization of the remaining supplies.

Anthracite differs so from other coals in character and mode of occurrence that its mining and preparation is quite at variance with the exploitation of bituminous coal. Owing to the steeply inclined character of its beds and its tendency to include thin seams of slate, anthracite requires a more elaborate and costly system of mining and in addition must undergo a more intricate process of mechanical treatment before it is suitable for marketing. The mining of anthracite is pictured in figure 5, which shows the elastic technique necessary to follow the rapidly changing inclination of the folded beds. The sharply inclined character of the deposits also gives rise to serious drainage problems, reflected in the circumstance that some ten tons of water must be raised for every ton of coal produced. Some of the coal seams are mined in the open, after the overburden of soil and rock has been removed by mighty steam-shovels; enormous areas in recent years have been laid bare by this large-scale method of exploitation. While the early mining of anthracite was very wasteful, marked improvement in engineering practice has taken place with the development of the industry. The mining of anthracite as to efficiency is now in sharp contrast

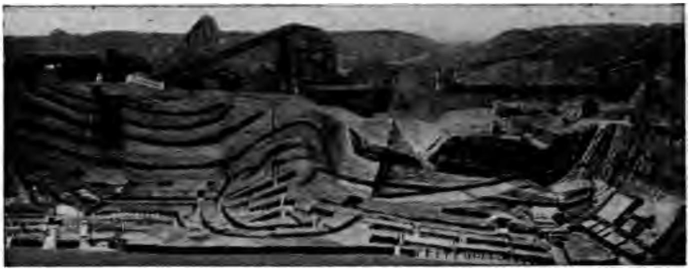
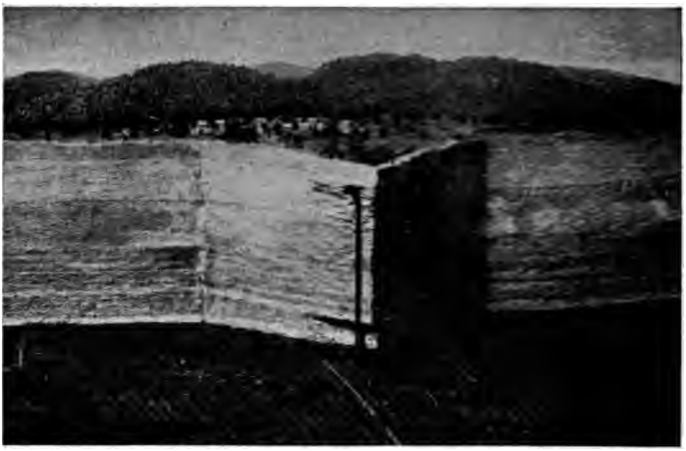


FIG. 5. The occurrence and mining of anthracite coal.

to the conditions under which most of the bituminous coal is still produced.

As it comes from the mine, anthracite is a mixture of coal, slate, and dirt, which must pass through an elaborate process of treatment before it becomes the commercial product with which the consumer is familiar. The coal must be separated from the impurities and graded according to sizes desired by the trade. This work is done chiefly by machinery in large structures called coal-breakers, which form prominent features in the anthracite region. As a result of years of mining, the refuse from the breakers, consisting of a mixture of coal-dust and slate, called culm, has accumulated in huge black conical piles, giving a somber aspect to the landscape. Much of this rejected material has lately been reworked with the recovery of valuable quantities of coal-dust, and much of it also has been washed into the mines to support the roofs, so that pillars of coal originally left could be recovered.

Bituminous coal occurs under simpler geological conditions than anthracite and in consequence is more readily won. As the beds of bituminous coal are prevailingly flat, or nearly so, the typical bituminous mine consists of a shaft connecting with radiating galleries which give access to a labyrinth of rooms separated by walls and pillars of coal left to support the roof. With the use of this room-and-pillar method of mining, frequently as much as half of the coal is left in the ground. (See figure 6.) Some beds of bituminous coal are mined by an ingenious method called long-wall mining, in which the entire seam is removed progressively from the periphery of the workings, the roof being permitted to subside as the workings advance. Also, of late, open steam-shovel mining has come into play in some localities, where the beds are sufficiently near the surface.

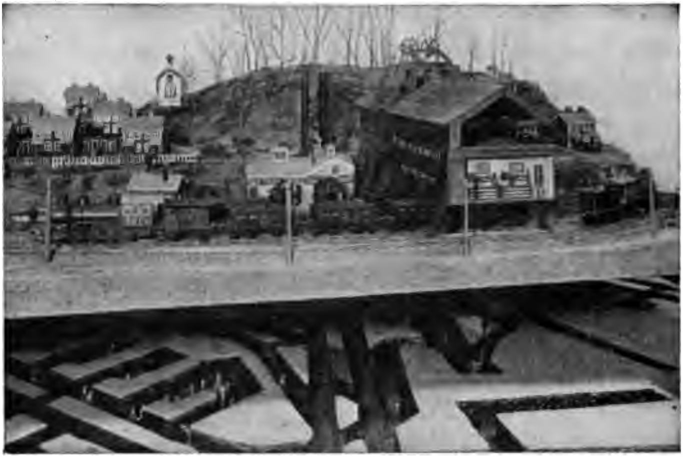


(Courtesy of the Division of Mineral Technology, U. .S National Museum.)

FIG. 6. Model showing the room-and-pillar method of mining bituminous coal.

Unlike anthracite, bituminous coal does not require elaborate mechanical treatment before marketing. Because of its ready combustion, it does not have to be reduced to small, accurately graded sizes; nor is it usually penetrated by thin seams of slate which must be removed. Bituminous areas, therefore, are not characterized by coal-breakers or extensive piles of waste. Such simple treatment as is ordinarily desirable is effected automatically as the coal flows down an inclined plane from the head of the shaft into a coal-car. Some dirty bituminous coals require milling and washing, but the treatment is simpler than that accorded anthracite. A striking feature of bituminous mining is the lack of developed methods of storage, because of the tendency of the product to crumble and even take fire, which requires a steady flow of coal-cars past the mine mouth so long as the mine is operating. (See figure 7.) A shortage of coal-cars, in consequence, means a stoppage of coal-mining.

The production of coal in the United States is so wasteful, not only of coal itself, but of labor and capital as well, as to raise the question whether the status of coal-mining is adapted to the conditions under which coal occurs and the needs which coal must meet. Passing over anthracite, because it is not inherently a necessity and because, moreover, its production is effective both as to engineering practice and coördination of operations, we find that the mining of bituminous coal is so widely scattered and loosely organized that the aggregated activities are to be looked upon as an industry only in respect to their common purpose. The country's most basic resource is produced through the medium of a thousand disintegrated units, working without concert and under conditions of destructive competition.



(From a model in the Division of Mineral Technology, U. S. National Museum.)
FIG. 7. The mining and transportation of bituminous coal.

Bituminous coal-mining as an industry is beset by conditions which are the occasion of present wastefulness and the justification of apprehension for the future. Scattered and unorganized, most of the individual companies are small and financially weak; inadequate coöperation in engineering practice exists; new technical developments are slow of growth; coal is mined for the most part by obsolescent, long-established methods. With no means of storage developed, the average mine can produce coal only when railway cars stand ready to receive it; a fluctuating demand, accentuated by seasonal variations, leads to instability of operations; many mines must close down in slack months, with destructive effect upon the conditions and supply of labor. The supply of labor also is not equal to the capacity of the developed mines; hence a labor shortage always devolops in periods of prosperity, when the demand for coal suddenly increases. For years until recently the price of coal at the mine ranged from $1 to $1.15 a ton, a figure so low that only the best and most easily obtainable coal could be extracted by the cheapest methods of mining, irrespective of the waste involved; the tonnage of thin-seam and high-cost areas sacrificed in the process amounts to more than half the total coal produced to date. Many districts have been burdened with a leasing system that obligated the company to remove a given tonnage each year, irrespective of market demand or price, with the result that the richest portions were drawn from seam after seam with irretrievable loss to present needs. The fixing of wages on the basis of thick and easily worked seams has imposed severe penalties upon inferior conditions, precluding the introduction of new and improved methods. Added to this, the policy of the Government, as exemplified in its anti-trust laws, has forbidden combinations and restrained coöperation, with the result that large-scale, standardized operations, a paramount and distinctive American achievement, are virtually lacking in the mining of coal.

The trouble with coal-mining is too much competition, resulting in a lack of balance between production, transportation, and distribution. Coal-bearing land is so abundant in the United States that an excessive number of mines have been developed. The productive capacity of the coal industry, in consequence, is far in excess of the requirements of the country. In addition, the demand for coal varies so from summer to winter that for the past thirty years the average working year has been only 215 days in length, leaving 93 possible working days when the mines were idle. Fluctuating operations have also created problems in the allocation of coal-cars, with enforced idleness in summer and congestion in winter. In times of slack demand, labor and equipment in large volume are forced out of employment. Depressed periods, in turn, are invariably followed by a hysterical demand and frenzied competition on the part of consumers, who are apt to place orders far in excess of their requirements. The coal industry is unstable, speculative, and unreliable alike to producer and consumer. The crying need is for stabilization. With proper operation, an excess mine capacity of some 150,000,000 to 200,000,000 tons and an excess labor force of some 150,000 men could be eliminated.

These conditions are particularly undesirable because they concern a product of fundamental importance. In efficiency of production, the coal industry is not to be compared with the other great basic industries, such as the iron industry or the copper industry. The difference is to be attributed to the competitive system of small-unit mining, which has prevailed in this country and indeed been perpetuated against a natural tendency otherwise, by a public policy hostile to combination. The individual coal producer cannot be held responsible for the backward status of coal production. In any attempt to recover more coal—that is, to make real progress in coal mining—he faces the handicap of destructive competition, the opposition of governmental restrictions, and probability of financial loss. The three form usually an insuperable obstacle to substantial progress, although a considerable advance is to be noted in many creditable instances.

The basic importance of coal and the growing incapacity of the resource to function adequately under the present system of exploitation will ultimately force a revision in favor of integration. Progress toward coördination of mining activities, in place of the present disjointed and discordant methods of output, will come along with a conception of public utilities broadening to the inclusion of coal. A public utility may be defined as a necessity which does not lend itself to competition. Thus far, the water, gas, electric, and traction service in municipalities, and to a less explicit degree the telephone and transportation systems of the country, have come under public oversight, as public utilities, unrestricted competition having been found inexpedient in these instances. Coal is likewise a necessity which does not lend itself advantageously to competitive methods of production, and under a growing need for efficiency in the administration of coal, this substance may be expected to travel the same course as its predecessors and eventually come to be regarded as a public utility and subject to public oversight. Coal-mining will then be conducted as a highly organized enterprise, gaining the advantages of coöperation and integration, with the dangers of monopoly safeguarded by proper governmental regulations.

In anthracite is found an interesting spokesman of this tendency. The anthracite industry began with many competing units, but the smallness of the field made combination easy and led to the merging of the rival interests in a unified organization. The purpose of the combination, judged by the results, was twofold,—to raise the price of anthracite and to increase the efficiency of mining. The disadvantages of the first were commonly recognized, but not the advantages of the second, which were equally significant. Through its monopolistic control of a recognized necessity, the combine years ago became a matter of public concern and the Government faced these alternatives in meeting the problem thereby raised: it could either recognize a combination in restraint of trade, and order its disintegration; or else accept the combination as a procedure essential to the proper handling of the resource, and impose suitable restrictions on the basis that the activity had become automatically a public utility. The first procedure was adopted and the combine was dissolved in so far as its legal existence was concerned; but at bottom the combination persisted, because it was inherent in the nature of anthracite development and could not be legislated out of existence. The alternative chosen by the Government was impossible of execution. It is common knowledge that the anthracite companies to-day operate in concert and fix prices by circular announcements at rates suitable for the effective operation of both high-cost and low-cost mines. As a result, anthracite is mined efficiently despite laws opposing the means to that end.

The bituminous industry deals also with a necessity that is lending itself less and less to competitive production. Competition is incompatible with economy, because coals expensive to mine cannot compete on a commercial basis with those which may be mined cheaply, and the two, in general, occur in such intimate association that the first, under present conditions, must be sacrificed in order to get the second. If the price is arbitrarily fixed high enough to cover the extraction of high-cost coal, society will pay too much for low-cost coal. If, on the contrary, the price is allowed to seek a natural level, the high-cost coal cannot be extracted and much of it becomes permanently lost. It may be asserted that we should use up the cheaply obtainable coal first and then later, when necessary, turn to the coal more expensive to produce. Such would be advisable were it not for the fact that the two occur intimately mixed, and we cannot later return and glean the unused values. This limitation is set by the geological occurrence of coal and cannot be changed. The only way by which coal can be mined effectively is for the price to be adjusted to the mining costs of each mine, and even to those of different parts of the same mine. Obviously, this would require a pooling of interests,—in short, integration.

The importance of coal wastage has been generally underestimated, on the assumption that our supplies of coal are virtually limitless. In the words of George Otis Smith, Director of the United States Geological Survey:

> The fact that more than half of the world's coal reserves are believed to lie within the territory of the United States has led too many of us into unwarranted optimism. The captains of the great industries concen-

trated along the Atlantic seaboard will do well to think less of the millions of tons that are said to lie awaiting their need in various parts of this continent-wide country of ours, but rather to ask for details as to where this coal is and how available it is for the use of this and the next generation. The total tonnage involves strings of figures hard for us to comprehend, but the tonnage remaining in the great producing fields of the East is so limited as to compel us to foresee their exhaustion within periods of the same magnitude as those which you executives figure as the expectancy of life for your industrial enterprises. For example, the Pittsburgh bed in Pennsylvania was estimated forty years ago as good for thirty generations, but the rate of mining has so greatly increased that now we must measure the exhaustion of this largest bed in the Keystone State by the space of a single generation. This is not an exceptional illustration of the shortened life due to unexpected increase in drafts upon our coal resources, for in the Georges Creek field in Maryland this same bed, there called the ''Big Vein,'' was believed forty years ago to have a life of at least 150 years, but to-day the field is regarded as almost worked out. Even if you turn to a less nearly exhausted field, such as the Pocahontas, the earlier optimistic calculations of an expectancy of life of four or five generations are now reduced to three or even two.

But the sheer waste of coal itself, serious as that is, is not the only toll to be debited against present conditions of coal production. There is the human element to be allowed for,—the unnecessary use of man-power in a disagreeable form of work, the loss of life and limb to an unwarranted degree, and perhaps most of all the instability of operations resulting in periods of unemployment and social unrest. Even all these circumstances might not seem so undesirable, at least to the investing public, if there were significant profits in the mining of bituminous coal; but from a financial point of view, the mining of bituminous coal is by and large a dull proposition. The Federal Trade Commission writes in its report to Congress on the coal situation in 1917:

> For several years prior to 1916 it was a matter of general knowledge that the bituminous coal industry in the United States was in an unsound condition. In this basic industry, so necessary to the industrial life of the country, conditions had developed so that it was demoralized financially, wasteful methods of mining resulted in the permanent loss of millions of tons of coal that could have been saved otherwise, the existing mines through lack of demand were kept idle from one-fourth to one-third of the working time, with consequent hardship to labor.

Along similar lines, George H. Cushing, Director of the American Wholesale Coal Association, has stated:

> . . . the difficulties inherent in the coal trade are so great that when understood they have discouraged organized capital from launching into coal on any large scale . . . the coal industry has been kept alive by the speculative spirit in business rather than as a result of the careful planning of well informed finance. . . . Because of the difficulty of controlling either the actual or potential competition in coal, organized finance cannot be persuaded to venture in any large way into the coal industry. As a consequence, we have never been able to get even large financial leadership for the rabble which has made up the coal industry.

Integrated coal-mining, under proper limitations, will reduce waste both of coal and of the human element, stabilize production, adjust supply to demand, lessen transportation, and hold the centers of coal production longer than otherwise in their present spots, to the advantage of the existing distribution of industrial activities, but it cannot be expected to lower the cost of coal to the consumer. For that purpose far-reaching changes in coal utilization alone will suffice. While the price of coal to the consumer has been too high, the price of coal at the mine has been, in general, too low,—so low, in fact, that it has been a small factor in the ultimate cost to the public. The price of coal at the mine mouth, however, has been slowly advancing; the upward tendency is natural and if left to itself will become stronger and stronger as more and more of the easy-to-get coal is mined. The price at the mine has been too low, because of the apparent abundance of easy-to-get coal; but within a very few years (if it has not already happened), with exhaustion of cheaply minable coal, the mining costs are bound to attain a rank more consequential in effect upon the ultimate price. It is even now very generally conceded that the "day of cheap coal is over." While integrated mining would add slightly to the average ton cost of coal at the mine, the effect would be to relieve the further upward tendency from the acute increase which present conditions will inevitably create. The result, in fine, will be to prolong to the utmost the period of cheap coal.

The advantages of integration in coal production are well known in other countries. The thin seams of the eastern coal-fields of Canada can be worked only under a coöperative system, as pointed out by the Canadian Department of Mines. Belgian mining law imposes the obligation of coöperative measures upon the coal-mining concessionaire. Coöperative coal marketing has been successfully practised in many parts of the world, notably Germany and the Transvaal.

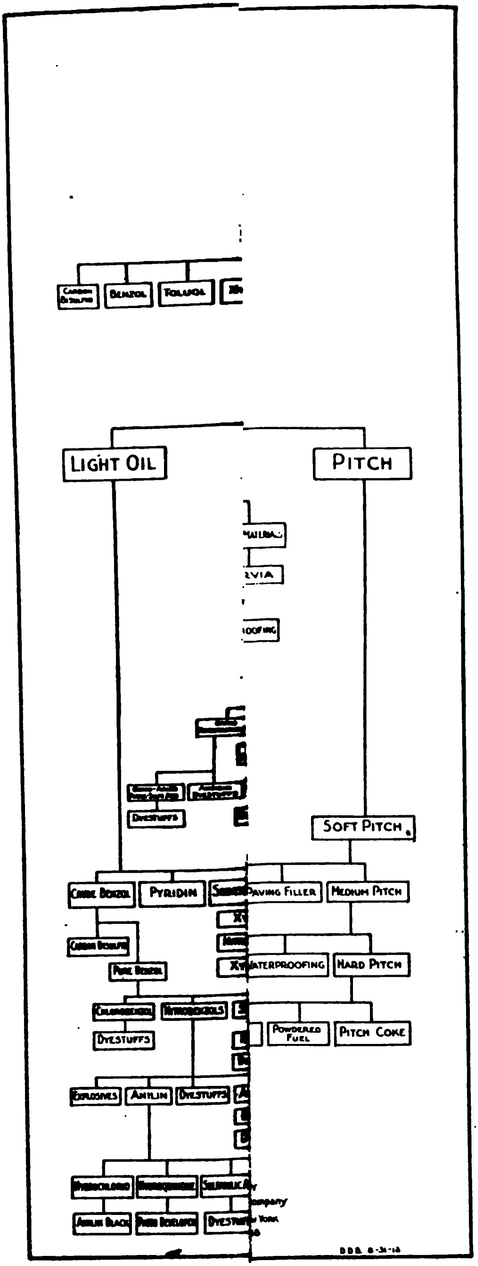
In short, coal as a resource demands coöperative measures of development. This is true of coal in peculiar degree and holds equally for few other resources. The reason is twofold. In the first place, coal deposits do not lend themselves, as do many other types of mineral deposits, to a graded extraction of values according to the strength of economic demand. In the second place, coal as the major source of power is the basis of modern life, and as such imposes upon organized society a direct responsibility to insure its most effective disposition.

In spite of shortcomings in production, transportation is the weakest link in our coal supply. Coal is over a third of the country's freight; the mining of coal is dependent upon an unbroken movement of coal-cars past the mine mouths; the number of coal-cars has never been equal to the full capacity of the developed coal-mines. With every period of industrial prosperity a car shortage is bound to occur. Moreover, as a result of the size and industrial status of this country, the railways have a sufficient responsibility without the carriage of coal. The haulage of much of the coal represents waste effort, as the energy can be concentrated in the coal-fields and transmitted through pipes in the form of gas or over wires in the form of electricity.

As developed in detail in Chapter VIII, the exigencies of transportation will force a radical revision in the distribution of coal, with the ultimate establishment of great power-stations in the coal-fields for the extraction of the energy from coal at the points of origin rather than at the manifold points of use. The advantages accruing to the energy resources themselves under such an arrangement are so great and also so in keeping with the by-product possibilities of coal and the latent significance of water-power, that such an outcome may be expected rather quickly to come into existence, especially in the congested industrial district of the northeastern States.

A notable start, indeed, has already been made in this direction under Government auspices. A Superpower Survey has been authorized by Congress and is actively at work upon a plan to develop a unified system of electrical transmission lines to serve the power needs of the industrial zone extending from Washington to Boston. At the outset the work was focused almost entirely upon the power needs of this industrial territory, but as the survey has progressed, its efforts have enlarged to consider the energy requirements of the field, which include both heating and power, and likewise involve the element of multiple production with by-product recovery of commodity values.

Turning now to the utilization of coal, we find that most of the coal produced in the United States is consumed for the energy contained in it, all else being disregarded. But coal is something more than stored-up energy; it is the source of a multitude of valuable products. Indeed, it is a veritable treasure-house of values, in this regard far surpassing any other type of mineral substance. Upward of a thousand coal products are in use to-day, some of them filling needs less conspicuous but just as vital as the need for fuel. Figure 8 shows the wide range of these products, affording essentials in agriculture, pharmacy, painting, paving, water-proofing, wood preservation, and an ever widening circle of other requisites touching every aspect of human life. And the development of coal products is still in its infancy. A few years ago and few of these products were known. To-day chemical vision can see no limit to the unfoldment in prospect. The boundary of this field is like the horizon,—always in sight but never to be reached. There can be no full utilization of coal which fails to take these matters into account.


Benzol
Toluol
Light Oil
Pitch
Roofing
Dyestuffs
Soft Pitch
Crude Benzol
Pyridin
Paving Filler
Medium Pitch
Carbon Bisulfide
Pure Benzol
Waterproofing
Hard Pitch
Chlorobenzol
Nitrobenzols
Powdered Fuel
Pitch Coke
Dyestuffs
Explosives
Anilin
Dyestuffs
Hydrochlorid
Hydroquinone
Sulfanilic A
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Present utilization of coal, therefore, involves a very low recovery of the energy content and an almost total loss of the commodity values present. This, of course, necessitates the production, transportation, and distribution of a much larger quantity than would otherwise be required; concentrates the whole cost, in respect to the consumer, upon the modicum of energy extracted; requires the imports of materials which might be manufactured from the non-energy components; holds back the development of latent possibilities in coal products; besmears with dirt and smoke an untold wealth in civic improvements.

At the present time a very small proportion of the coal consumed is adequately used. Putting to one side anthracite, which, having lost its volatile constituents in the course of its strenuous geological history, has an energy value merely and therefore yields a reasonable service in its crude state; and counting off about one-twelfth of the bituminous coal, the portion subjected to by-product recovery in connection with the manufacture of coke; we find that there still remain each year in round numbers half a billion tons of coal which are consumed in the raw condition with a total loss of the commodity values and an incomplete recovery of the energy. The sum total of this loss represents the margin between present attainment and full utilization, and may be presented in tabular form, as follows:

THE NEGLECTED OPPORTUNITIES INVOLVED IN THE

[All figures in round numbers

Present Attainment		Possible Attainment		
Coal inadequately used under present conditions	Recovered under present conditions	Available under present technical knowledge and ultimately recoverable under stimulus of constructive economic policy		Loss interpreted in terms of dollars on basis of normal (1915) values
500,000,000 tons.	A small percentage of the energy.	Energy...	At least double the present recovery. (On basis of widespread utilization of gas in place of solid fuel, etc.)	$1,000,000,000+ in needless mining and transportation of coal.
		Nitrogen (ammonium sulphate).	5,000,000 tons. (On basis of 20 pounds per ton coal.)	$280,000,000 .....
		Benzol....	1,000,000,000 gallons. (On basis of 2 gallons per ton coal.)	$300,000,000 .....
		Tar......	4,000,000,000 gallons. (On basis of 8 gallons per ton coal.)	$100,000,000 ..... Additional value of coal-products manufactured from benzol and tar.
		Total..	....	[a]$2,000,000,000...

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[a] This figure is given as a concrete expression of the magnitude of the opportunity that faces this country in respect to coal, although the significance of the prospect is conveyed more truly in the two columns to the right. The matter, of course, can not be expressed in figures without quali-

The question naturally arises, why this preponderant inadequacy in coal utilization? This is no simple matter to explain; the reply that the in-

WASTEFUL USE OF COAL IN THE UNITED STATES

and on an annual basis]

Possible Attainment		
National meaning of loss under present circumstances		National gain from correct practice
Needless burden upon overworked railways. Smoke nuisance in cities, entailing untold destruction of civic betterment attainments. High cost of coal to consumer. Resource waste.		Some relief to transportation. Complete elimination of smoke. Cheaper fuel.
Serious nitrogen problem affecting fields of fertilizers and explosives. Dependence upon Chile for sodium nitrate. Large expenditures for atmospheric-nitrogen plants. High cost of nitrogenous fertilizers, reflected in cost of food.	Inadequacy of coal-products industries. Problems in explosive manufacture.	Nitrogen independence, contributing to food production and explosive manufacture.
Undue dependence upon gasoline as motor fuel, contributing to overproduction and rapid exhaustion of the petroleum resource.		Contribution to supply of motor fuel. Advancement of good-roads movement. Establishment of large coal-products industry. Gains in new directions to be developed by chemical research.
Neglect of roads.		
....	....	Capacity for relieving cost of living $10–$20 annually per capita. Gain to American industry.

fications, which, therefore, muse be accepted on the basis of the argument in the text. An element of double count in the summation is compensated by increments resulting from the course of advancement in multiple production.

dividual user, whether an industry, a community, or a householder, finds it cheaper to consume raw coal than to dispose separately of its various values is true but superficial. Such procedure is not cheaper for the users in the aggregate; also, there is no lack of technological knowledge requisite to fuller recovery of the values in coal. The shortcoming, then, cannot be due to lack of desirability or to lack of technique. The default must be credited against economic conditions. And as the United States in the past has possessed no governmental activities engaged in shaping and stimulating industrial developments, the responsibility reduces itself to the fact that industrial enterprise has not seen fit to go into the matter. Either the opportunity has not been apprehended or industrial enterprise, cognizant of the situation, has not been interested. The latter is undoubtedly the true explanation.

For this lack of industrial initiative a blend of several factors is responsible. In the first place, America has been full of opportunities for volume production, and consequently business enterprise has not been forced by the stress of narrowing industrial opportunities to turn to the far more complex field of multiple, or by-product, production; only where the opportunities afforded in this direction were outstanding and marked has the inducement been responded to, as in the case of by-product coking, petroleum refining, etc. Secondly, any given project, on contemplating the prospect, faced a situation in which the establishment of production would yield by-products, the consumption of which required other industries which in turn would contribute other products calling for still further activities; hence a project at the source would undoubtedly see its contemplated output ranging off into hypothetical regions not yet established; while a project viewing the matter farther out would regard its proposed position as bearing some resemblance to an island in a sea of non-development. The requisite reach of coördination was evidently not self-accredited on the part of industrial enterprise. Then, again, the field has opened up fully only of late, so that the full measure of the opportunity has not been of long standing.

In addition to these considerations, there has been no competitive spur to action. The loss represented in the wasteful consumption of raw coal was not felt by any given industry, since the wastefulness was universal and the cost under this head was a more or less uniform item which was shifted in its entirety to the shoulders of the consuming public. The need for advance also was not generally appreciated, inasmuch as there was plenty of fuel; transportation difficulties had not loomed up; coal products could be purchased from Germany; nitrate could be imported from Chile; and, in general, the whole matter of coal was taken for granted.

Hence, industry had no particular incentive for entering a new field which, while large, was intangible. Moreover, industry under the old order faced decided limitations in its recognized inability to construct a proportionated demand for the whole range of prospective products. On the other hand, the public, which was actually paying the cost of the inadequacy, but under a disguised heading, did not see its concern in the matter; nor was public interest represented by machinery charged with acting on popular behalf: public utilities commissions, the nearest approach to such machinery, were notoriously weak and shallow; the Federal Government, lacking the pressure of public opinion, did not take up the issue. So the course of progress was short-circuited, and the tremendous possibilities in our unrivaled coal resources remain to-day virtually untouched. The industrial progress of this country has been sustained by the mining of an ever increasing quantity of coal, until the very bulk of the total has become a critical weakness in this country's industrial life.

Such is the situation. The utilization of coal is extravagantly wasteful from beginning to end, the wastefulness is a matter of uniform practice not subject to improvement through avenues of individual enterprise, and, contrary to general notions, it is the public at large, not industry itself, which stands the loss from the shortcomings in the situation and which is, therefore, primarily concerned in its betterment.

The public is concerned, because it pays the bill rendered by present wastefulness and will reap the gain accruing from any progress toward competency. The net advantage will not merely represent the margin of value now lost, but in addition will include the border of advance added by the multiplication of values over those calculable from the point of view of the present. The total gain cannot be expressed in exact figures; indeed, it is in no sense a fixed quantity, but is entirely dependent upon the length to which the future carries the matter from its present chaotic stage. But apart from the prospect of future gain, the maintenance of the situation as it now stands is actually costing money. There is no apparent reason why fully coördinated development should not look toward a fairly complete recovery of at least the leading by-products in coal, and this prospect would definitely entail the doubling, if not the trebling, of the fuel efficiency derivable. This means that our present annual coal output could be made to more than double its service, or—accepting the current service requirement as a standard—that less than half the output can do the present work and in addition make heavy contributions to the supply of fertilizers, motor fuel, and chemical products. The total loss, on the basis of this estimate, runs well above a billion dollars a year, or over ten dollars for each inhabitant of the United States. Of such measure is the average man's pecuniary interest in the full utilization of coal.

Improvement in coal utilization cannot be relied upon to come from industrial stimulus alone, but must be brought into effect as the result of public interest in the matter. The means for starting toward this accomplishment are set forth in Chapter VII, as lying in the direction of enlarged municipal gas-plants, which will handle all the coal needed by the community with the production of solid fuel, gas, and the by-products ammonia, benzol, and tar; or else, gas and by-products only.

Through the principle of multiple production, therefore, coal can be forced to render up its full quota of service. This is a new economic force, one scarcely recognized as yet as a principle which may be constructively applied. Yet the principle of multiple production has been gaining headway for years, and by means of it the multiplying needs of man are being met from virtually a stationary range of raw materials. The rôle of multiple production is rapidly enlarging; it represents a principle that must come into play more extensively to relieve the strain falling upon natural resources and transportation. Through the agency of chemical knowledge it serves to create a divergence of products, each the starting-point of a second diverging series. The principle of multiple production is peculiarly applicable to coal; only by the use of this principle, brought into effective action under the guidance of an enlightened economic policy, can adequate values be extracted from this material.

In Europe, with the necessity for economies in fuel consumption, far greater advances in the utilization of coal have been attained than in the United States. And these advances, it may be observed, are such as to lend the encouragement of successful experience to the changes in coal utilization demanded by the needs of our own situation. The status of the British gas industry is higher than that of the corresponding activity in the United States; while the by-product distillation of coal, as is well known, has been carried further in Germany than elsewhere, resulting in the strong position attained by that country in the manufacture of dyestuffs, chemicals, and explosives. Noteworthy progress abroad centers also around the development and use of producer gas, the briquetting of low-grade coals, and to a limited degree around the manufacture of domestic "coke."

Producer gas is the result of the complete gasification of coal under the action of a mixture of air and steam. Both high-grade and low-grade coals may be employed in its manufacture and the gas may be produced with or without the recovery of the by-products ammonia, benzol, and tar. Before the war most of the foreign by-product producer plants, however, made adequate recovery of the ammonia only. The producer principle is not only successfully applied to central plants manufacturing gas for transmission as such or for the generation of electricity, but it is also employed in smaller and more mobile installations, known as suction plants, in which the gas-producer and gas-engine are a single unit. The suction plant, therefore, adapts raw coal to immediate use in the internal-combustion engine, combining the efficiency of the latter with the mobility of the steam-engine. This producer gas is suitable not only for large service stations, but also for small industrial plants and even for marine engines and locomotives. The manufacture of producer gas from coke, peat, lignite, and high-ash mine refuse has become so thoroughly established on the Continent as to be a common-place procedure. The wide-spread use abroad of the producer-gas principle has brought into competition with high-grade coals used as such, the low-grade coals and coal-like substances needed to supplement a limited fuel supply.

The briquetting of low-grade lignite coals and coal slack has been successfully practised in Germany and other European countries for over thirty years, thus, together with the results attained by producer gas, bringing into service types of coal largely unused in the United States. A number of special forms of fuel coke, approximately artificial anthracite, have met with some measure of success, especially in England, where they are sold under the trade names of coalite, charco, coalexld, and others; while in the United States the development of a smokeless fuel under the name of carbocoal has attracted considerable interest.

In view of the advances in the utilization of low-grade coals abroad, we are led to inquire as to the potentialities of similar coals in the United States, which have heretofore not been called into service because of the prevalence of more desirable grades. Low-rank coals are very abundant in this country as shown by the United States Geological Survey, whose results may be summarized and expressed in round numbers on a per-capita basis, as follows:

COAL RESERVES OF THE UNITED STATES
CALCULATED TO A PER CAPITA BASIS[a]

	Now underground	Mined to Jan. 1, 1921
	Tons	Tons
	190	31
Bituminous coal	15,000	110
Lignite coals[b]	20,000	([c])

[a] The calculations are made by the writers from data presented by Marius R. Campbell, The Coal Fields of the United States: General Introduction, Prof. Paper 100-A U. S. Geological Survey, 1917. The figures are given in round numbers based on a population of 100,000,000.

[b] Includes sub-bituminous coal, which is between lignite and bituminous coal in quality.

[c] Virtually untouched.

The deficiency of anthracite and the preponderance of lignitic coals are at once apparent. It is shown in Chapter VII, that the undue dependency on the small and waning anthracite reserve may be relieved by a suitable by-product utilization of bituminous coal. The further application of the same principle will likewise lend significance to our lignitic coals, tending to raise their value from little or nothing to a point justifying their adoption in the place of higher-rank coals in those regions, at least, in which lignites alone occur. And in this connection, it should be noted that lignitic coals are found chiefly in the Dakotas, Montana, Wyoming, Colorado, Arizona, New Mexico, Texas, and Louisiana, in sections largely free from other coal resources.

Considerable experimental work in this country has already been directed toward making lignites effective sources of heat and power. Because of their high moisture content and tendency to "slack," these coals are not suitable for transportation like ordinary coal. Efforts toward burning them in powdered form, with the effect of gaseous fuel, or of compressing them into briquets have met with some success, and great possibilities are afforded through complete gasification in gas-producers, or by carbonization with by-product recovery. The Bureau of Mines has demonstrated that 1 ton of air-dried lignite may be made to yield 8,000 to 10,000 cubic feet of gas, 17 pounds of ammonium sulphate, 1 gallon of oil, 50 pounds of tar, and ½ to ⅔ ton of carbon residue convertible into briquets approaching the value of anthracite. Thus may even the coals lowest in rank be raised to meet the social needs for smokeless fuel and economy.

In recent years, a new and interesting field has opened up in connection with the consumption of coal in powdered form. It has been found that coal, when finely pulverized, may be burned with an effect very similar to that obtained from the combustion of gas. Powdered coal, therefore, gives a highly concentrated heating effect combined with an ease of manipulation and a favorable thermal efficiency. The use of powdered coal has become common in cement kilns and certain metallurgical operations, where a long hot flame is especially desirable; and recently there has been a limited application of powdered coal to steam-raising purposes.

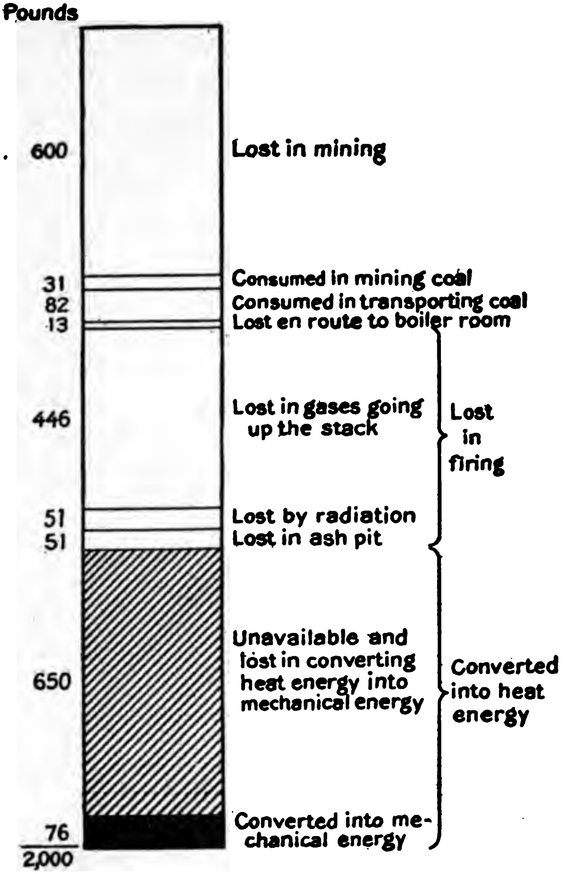
The advocates of powdered coal are very sanguine as to the possibilities of extension in the use of fuel in this form; but a serious drawback has been encountered in connection with the ash contained in the coal, which gives trouble in many operations by clinkering and in other ways. In this connection, however, recent experiments give promise that the ash-forming content of coal may be reduced to a harmless percentage very cheaply on a commercial scale; in which event, the possibilities of powdered fuel would be greatly enhanced.

It is perhaps too early to foresee with any clarity the ultimate economic status of powdered coal, if it can be rendered virtually ash-free, but the process on the one hand offers a competitive line of development with by-product practice, while on the other it enmeshes with and supplements the possibilities inherent in the chemical refining of coal before utilization. On the whole, however, powdered coal would seem to offer an intermediate stage between the use of coal in solid form, as at present, and its consumption after extraction of the by-products and subsequent gasification; coming in for a notable development as a stage in the evolution of advancing efficiency in coal utilization.

In conclusion, then, the story of coal is "a story of waste, all the way from the face of the mine working to the smoke-stacks of the boiler plant—waste of a natural resource, waste of human endeavor, waste of capital, waste of transportation capacity, and waste of energy—and of none of these have we enough, much less to spare.'' Figures calculated by the United States Geological Survey and the Bureau of Mines go to show that of the average ton of coal exploited in this country, 600 pounds are lost in mining, 126 pounds are consumed between the underground working and the boiler room, 446 pounds are lost in gases going up the stack, 102 pounds are lost by radiation and in the ash-pit, 650 pounds are lost in converting heat energy into mechanical energy and only 76 pounds are left for application to useful work. The average small plant or locomotive in use today makes use of a small percentage of the heat units shoveled into it.

When it is recalled that 300 pounds of coal, even under the wasteful and inefficient manner in which it is now utilized, represents the labor equivalent of one man for one year, it is readily seen how significant the conserving of our fuel energy, and thereby our human energy, becomes.

The refining of coal to the end that its energy and commodity values may be more fully extracted; the development of means for transporting a greater proportion of our energy over wires in the form of electricity and through pipes in the



(After George Otis Smith.)

FIG. 9. Chart showing the average losses in bringing coal into use.

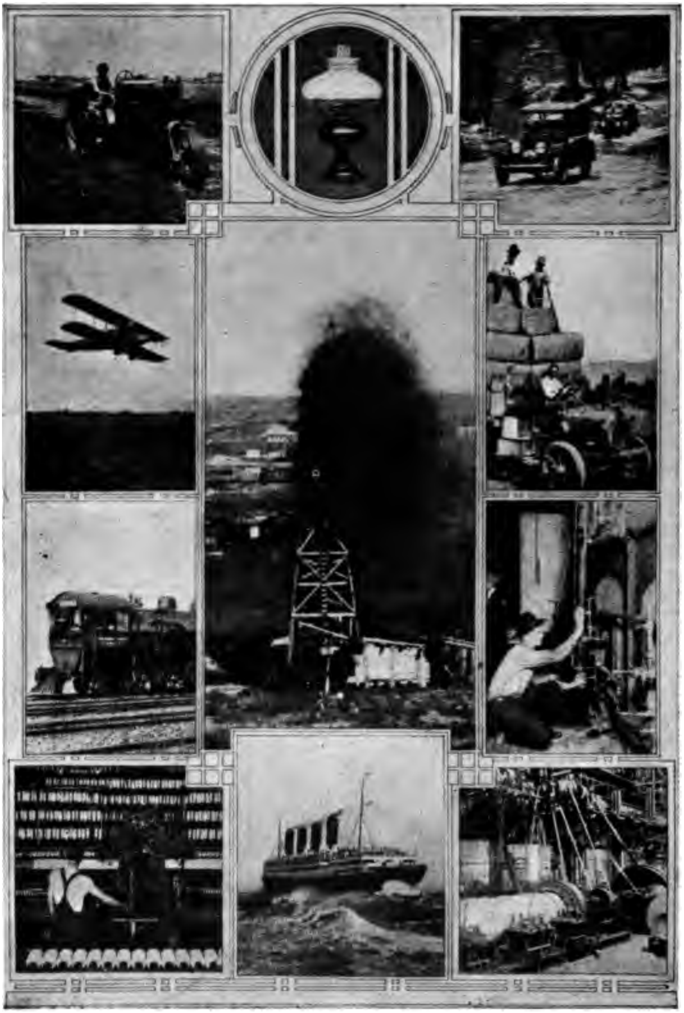
form of gas; improvements and developments in our appliances to the end that the energy may be more effectively applied are conservation needs of the first rank. As Herbert Hoover has remarked, the coal industry is "the worst functioning industry in the country." For adequate social and industrial advance, this industry should stand at the head of our basic industries, not at the foot.

CHAPTER IV

OIL, THE ACCELERATOR OF PROGRESS

PETROLEUM is of peculiar value to society because it is the sole source of gasoline, the dominant motor fuel; provides kerosene, the most important illuminant outside of cities; and yields lubricating oil, upon which the wheels of industry revolve. In addition, it has come to be an essential fuel in the Southwest and on the Pacific coast, where coal is lacking; is requisite to the operation of an oil-burning navy; and forms the starting-point for an oil by-products industry, a branch of chemical manufacture still in its infancy and offering unlimited possibilities of development. (See figure 10.)

The liquidity of the crude product makes petroleum unique among mineral raw materials, contributing wide commercial availability through the ease with which the substance may be mined and handled; while the magnitude of the resource has given confidence for the extensive mechanical de-



(Courtesy of Sinclair's Magazine.)
FIG. 10. Petroleum and its uses.

velopments essential to its use. Hence, the employment of petroleum is firmly established among the practices and needs of modern life, and any tendency toward disuse of its essential products, either through undue increase in price or from decline in production, will mark a turning-point in material comfort and industrial advantage, the deferring of which becomes an object of universal concern. As the petroleum deposits of the United States have been drawn upon with extraordinary rapidity and the supplies have already suffered serious depletion, the matter of their approaching exhaustion assumes the light of immediate importance. The comforting assertion that such considerations may be safely left to future generations does not apply to petroleum.

Petroleum—or crude petroleum, as the raw or unrefined product is often termed—is an oily liquid varying considerably in appearance, according to the locality from which it comes. It is an extremely complex mixture of organic compounds, chiefly hydrocarbons, but substances containing sulphur, oxygen, and nitrogen are also present in small amounts. It contains, therefore, five chemical elements of the first importance in life processes,—a circumstance that suggests at once an organic origin and determines the important rôle that this substance plays in filling the needs of man.

If crude petroleum is exposed to the air, it gradually thickens until a solid residue is left. The first product given off is natural gas; then liquid components evaporate in the order of their lightness; and the final residue is composed largely of either paraffin wax or asphalt. Petroleum is thus seen to be a mixture of different liquids dissolved in one another and holding in solution also natural gas and solid substances. This conception correlates natural gas as a by-product of petroleum and affords a simple epitome of the changes more rapidly induced when petroleum is subjected to refining. The asphalt lake of Trinidad and the ozokerite deposits of Galicia and Utah represent natural residues from the prolonged evaporation or natural distillation of petroleum.

While petroleums vary considerably in character, they fall chiefly into two classes, according to whether the residue yielded is predominantly paraffin wax or asphalt. This broad distinction is of great economic significance, because the paraffin petroleums, occurring chiefly in the eastern part of the country, came first into use and therefore determined the current refining practice and the existing demand for petroleum products; while the asphaltic petroleums, exploited later in the Gulf region and California, found their immediate commercial outlet in the form of fuel. The higher gasoline content of paraffin oils, coupled with the distance of coal from the California region, gave free scope to the economic differentiation of the two types.

Because of its liquidity, petroleum differs markedly in geological occurrence from all other minerals. It appears on the surface in some localities in the form of oil seeps, but commercial quantities of petroleum are found only at depth, inclosed within the rocks of the earth's crust. Its occurrence is very similar to that of artesian water, with which, indeed, it is frequently associated. It saturates certain areas of porous rocks, such as beds of sand or sandstone, tending to accumulate where such strata occur beneath denser, impervious layers. Occurring in this manner under the pressure that obtains at depths, carrying immense quantities of natural gas in solution, and almost invariably associated with water, petroleum is capable of movement and in general migrates upward until it encounters a layer of impervious rock so disposed in structure as to impede further progress and impound the oil into a "reservoir" or "pool." (See figure 11.)

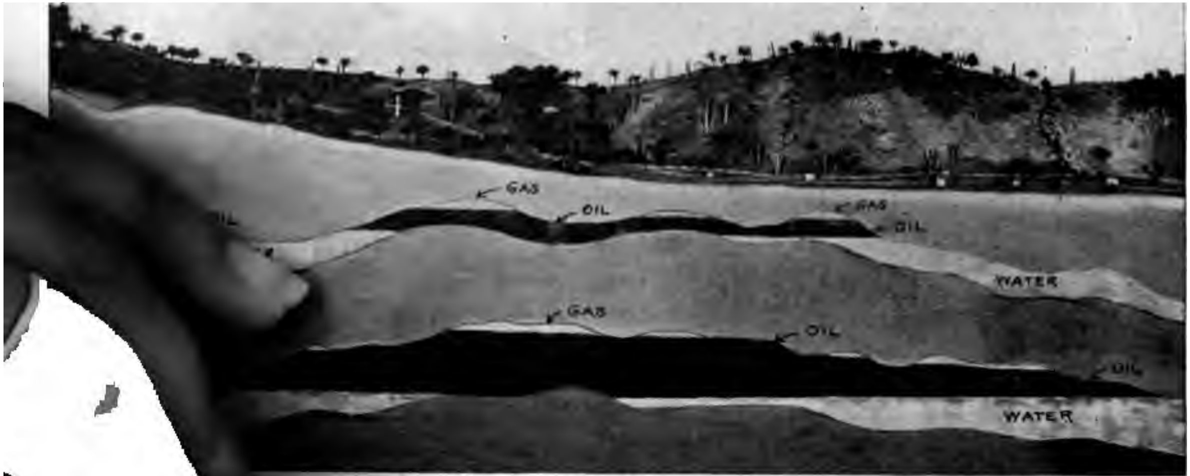


FIG. 11. The occurrence and mining of oil and gas.
(From a model in the Division of Mineral Technology. U. S. National Museum.)

The geology of petroleum, therefore, is the geology of rock structures, and the skilful mapping of the surface disposition of rock formations gives the means for determining the structure at depth and hence the position of structural features favorable to the accumulation of oil. When this information is supplemented by careful records of the rock layers encountered as wells are drilled, a three-dimensional knowledge of the earth's crust is obtained, remarkable for its detail and accuracy. Thus, with the aid of geological methods, the development of petroleum fields may be changed from a gambling venture to an exact science, and, if the scale of operations be sufficiently large, it may be figured rather closely how much oil can be obtained from a given expenditure of money. Instead of representing the most uncertain venture in the world, therefore, oil production can now be made as definitely an engineering project as the mining of a clay bank.

The migratory character of petroleum, coupled with the [illegible]al tendency of stratified rocks to [illegible] in[illegible] undulating folds and shallow [illegible]culia[illegible]nificance to the under- [illegible] on [illegible] oil deposit. Thus the [illegible] consists in puncturing [illegible] holds it in restraint so as to give free scope to a movement upward to the surface. Accordingly the position of the oil grows highly unstable as soon as the deposit comes under exploitation and this variability affects the entire geological unit or pool. In consequence the joint ownership or joint exploitation of a single pool results in the inability to apportion the product on any arbitrary basis of vertical boundary planes, and the oil, therefore, is virtually no man's property until it is got above ground. This circumstance is almost invariable and the customary method of exploiting the single oil pool by a series of small, independent holdings has cost an inordinate toll of waste and loss. The economics of oil production is out of adjustment with the geological occurrence of oil and the latter, being a physical fact, cannot be altered.

Few questions in geologic theory have met with more discussion than the origin of petroleum. It is reasonably certain, however, that petroleum in the main is of organic origin and represents the natural distillation products of plants and animals buried in the muds and oozes of ancient swamps and seas. Vast rock formations, indeed, are known which are nothing more than the accumulated debris of innumerable organisms, compressed, hardened, and changed into rock. Fossiliferous limestones, phosphate rock, and coal seams are familiar examples which underlie thousands of square miles of the earth's surface. It would indeed be strange if in the process of formation oils were not produced, when organic products to-day, subjected to heat and pressure, yield oily substances not unlike petroleum. Sediments carrying organic remains are sufficiently abundant and wide-spread to account for all the petroleum that the oil-fields of the world give promise of producing.

While petroleum is of very common occurrence in traces, areas underlain by commercial quantities are somewhat restricted and fields of great importance are few. Thus despite an intensive search for new oil regions and vigorous campaigns of development in all parts of the world, the entire supply comes largely from three countries, as shown in the accompanying chart (Fig. 12).

In the United States the output is derived from a number of widely scattered regions known as "fields," whose distribution is shown on the map (figure 13) and whose importance is indicated by the charts (figures 14 and 15). In a broad way, these fields fall into two groups,—those of the eastern half of the United States, bound into a single unit by an extensive system of pipe-lines, and those of California, connected with the rest of the country by railway transportation only. The intermediate fields of Wyoming do not come within this rough geographic classification, but with further development they will presumably be joined by pipe-lines with the group of the eastern half of the country. It will be observed that the Kansas-Oklahoma field of the eastern group and the California field are about equal in production

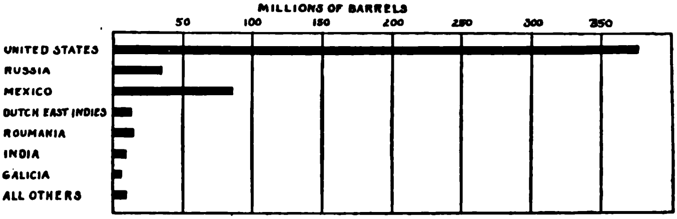


FIG. 12. World's production of petroleum in 1919.

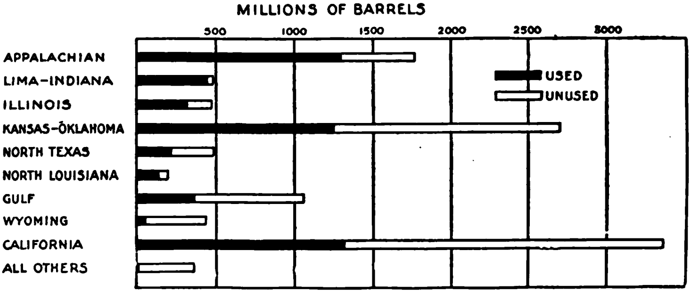


FIG. 15. Chart showing the approximate degree of exhaustion of the principal oil-fields of the United States in 1921.

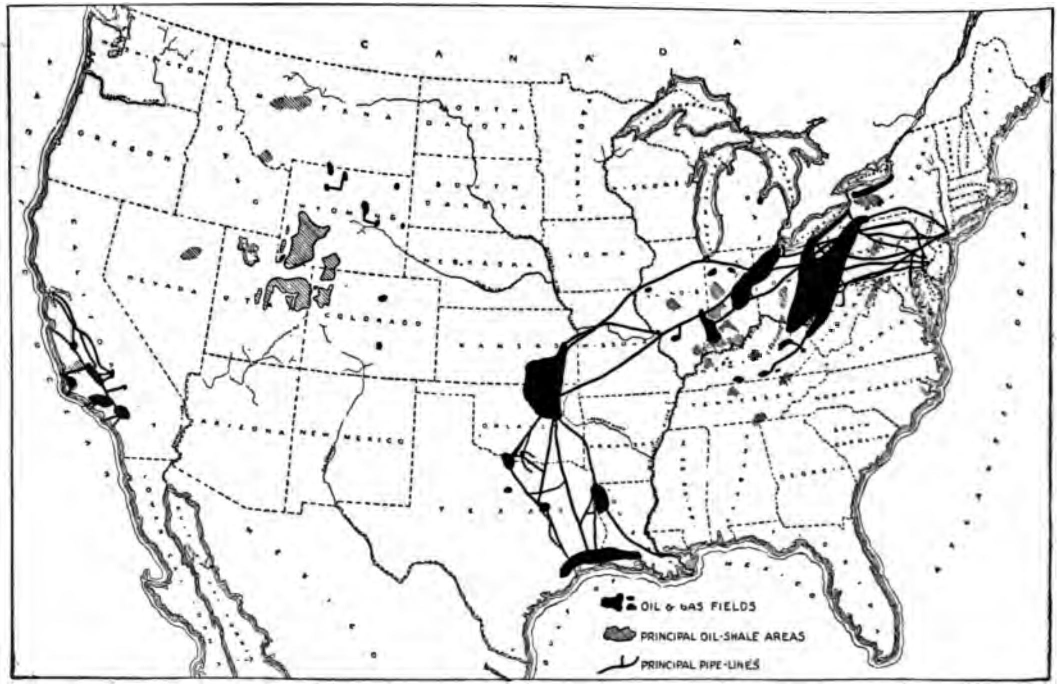


FIG. 13. Map showing the distribution of the oil and gas resources of the United States, together with principal pipe-lines.

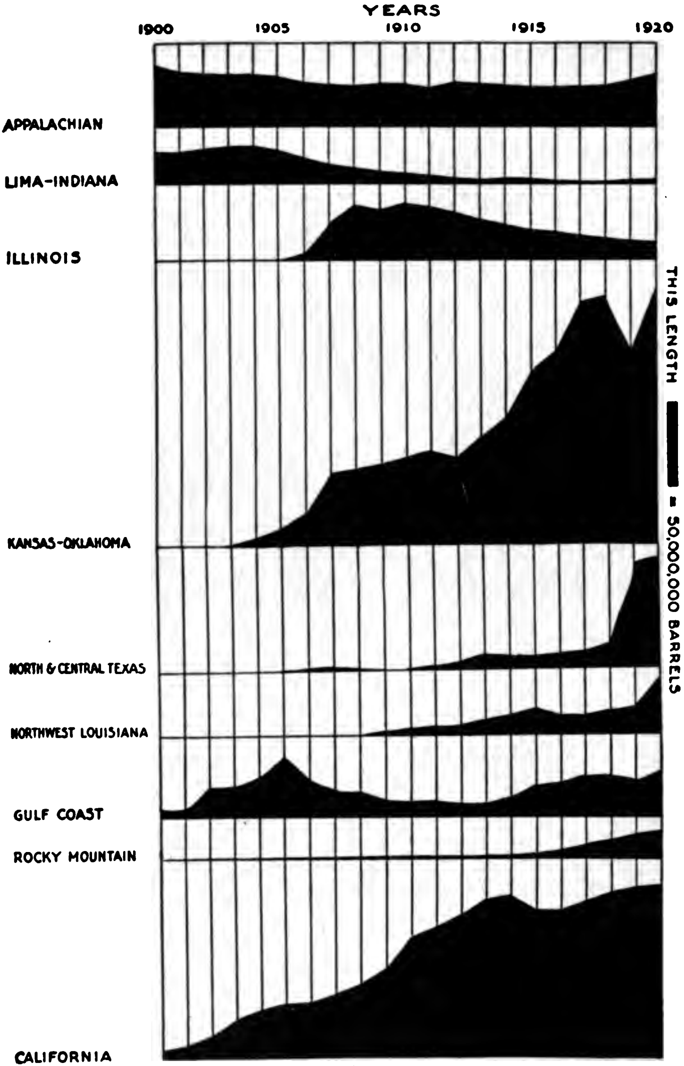


Fig. 14. The relative production of the principal oil-fields in the United States, 1900–18.

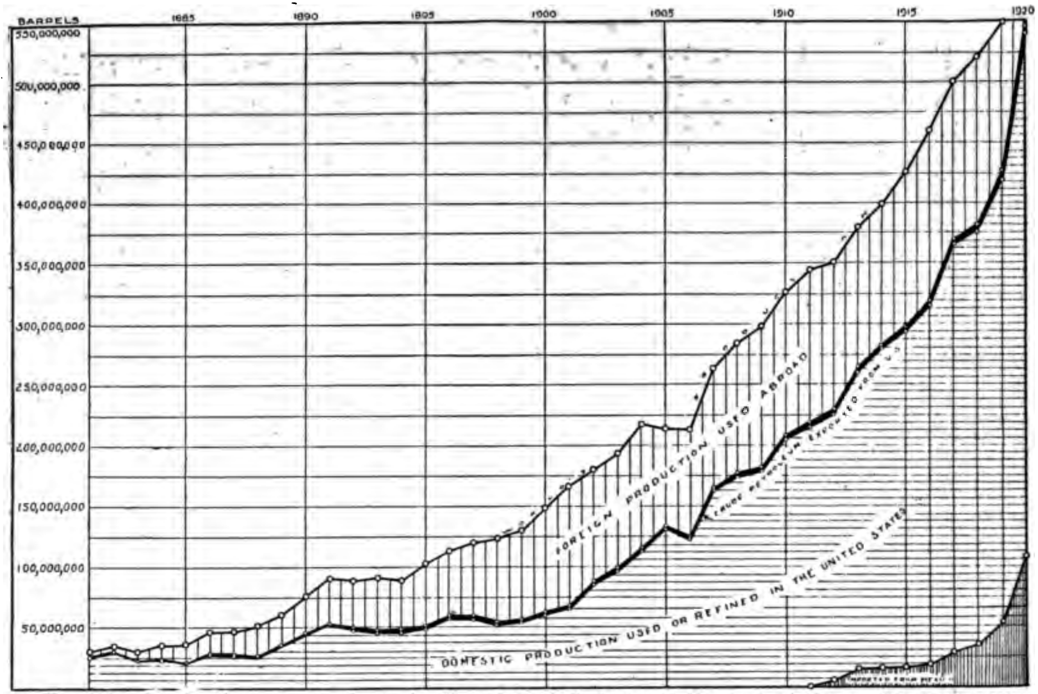


FIG. 16. Production of petroleum in the United States and the rest of the world, 1880–1920.

and dominate the petroleum output of this country, together contributing over half of the total supply.

The development of petroleum production in the United States from 1880 to 1920 is indicated graphically in the chart (figure 16). From the situation there depicted, two features of particular significance stand out,—the slow increase in domestic production up to 1900, less marked than the increase in the corresponding foreign production, and the rapid domestic growth between 1900 and 1920, contrasted with a nearly constant production for foreign countries during that period. This emphasizes the fact that since the beginning of the twentieth century, the rapidly increasing use of petroleum throughout the world has been met largely through the intensive exploitation of American deposits. Thus the United States has assumed a dominant position in respect to this commodity, producing now approximately 70 per cent. of the world's supply.

The activities concerned with the production, transportation, refining, and distribution of petroleum constitute the petroleum industry. In quantity, value, and importance of production, this industrial field stands among the foremost in the country. It is notable, especially, for the scope of its operations, which embraces diverse activities usually the functions of separate industries,—a characteristic due to the peculiar nature of petroleum. In most other industries, to cite the most striking distinction, transportation over alien lines separates the producing activity from the manufacturing activity, creating a break between continuity of operations; in the case of petroleum, however, the liquidity of the crude product adapts it to specialized transportation through pipe-lines, themselves a part of the resource development. In consequence, the petroleum industry in its ideal form represents a type of industrial activity more highly coördinated technically than other industries of the present day, affording, therefore, an important object-lesson for constructive consideration.

The petroleum industry, in point of fact, is not coördinated throughout, but at present breaks into two portions, by no means in complete adjustment,—the production of petroleum and the handling of petroleum with its threefold aspect of transportation, refining, and distribution. The conditions of producing crude petroleum are wholly different from those involved in its treatment after it is above-ground. This is reflected in the circumstances that over fifteen thousand individual companies are engaged in the mining of petroleum, while the organizations concerned with the handling of the product are numbered by a few hundred. A large part of the crude production, therefore, appears above-ground through the efforts of a great many small operators, while the bulk of the transportation, refining, and distribution is taken care of by a very few large organizations.

Petroleum is won in commercial quantities through wells drilled to varying depths in the crust of the earth. The drilling is commonly done by means of a heavy string of tools suspended at the end of a cable and given a churning motion by a walking-beam rocked by a steam-engine. This method is known as the standard or percussion system of drilling. The steel tools, falling under their own weight, pulverize the solid rock encountered and literally punch their way to the depth desired. To prevent the caving in of the hole, but especially to avoid the inflow of water from water-bearing formations, the well is lined or "cased" wholly or in part with iron piping, which is inserted in screw-joint sections at intervals during the drilling and forced down to positions needful of such protection. The well does not taper, but if deep, changes to successively smaller bores at several points, resembling in section a great telescope.

The drilling of an oil-well is graphically described by George Fitch in the following paragraph:

> An oil well is a hole in the ground about a quarter of a mile deep, into which a man may put a small fortune or out of which he may take a big one. And he never knows until the hole is finished. . . . It takes a couple of thousand dollars, several months, and a couple of noncommittal men in mud-plastered overalls to dig an oil well. They begin by going up about 60 feet. When they have finished their derrick, they hang a drill on it weighing half a ton. Then the men hitch the drill to an engine and punch a 42-centimeter hole in the earth's crust. Sometimes, after they have been punching away for several weeks, the hole blows the derrick into the sky, utterly ruining it. Then the owner shrieks with glee and employs 500 men to catch the spouting oil in barrels. But sometimes the derrick is as good as new when the hole is finished. Then the owner curses and takes the derrick away to some other place which smells oily.

Another method of drilling, known as the rotary system, also is in common use, being particularly adapted to regions where the sides of the well tend to cave badly, as in California and some other localities. This system requires more elaborate machinery than the standard, as the drilling and insertion of the casing are simultaneous. The iron casing, indeed, is tipped with a steel bit and rotated so as to bore its way downward like a great auger.

The oil-well is marked by a tall wooden framework called a derrick, which permits the string of tools and the casing to be inserted or withdrawn when necessary. It is the presence of derricks that gives the characteristic appearance to an oil-field landscape. Oil-wells vary from a few hundred feet or less in depth, requiring a few weeks only to drill, to those thousands of feet deep and demanding months of continuous labor before production starts. The deepest wells are slightly over 7,000 feet, but such depths are exceptional. The deepest well in the world, near Clarksburg, West Virginia, recently reached a depth of over 7,500 feet. The cost of drilling runs from $1 up to $25 or more a foot, while the rate of progress, except for shallow wells, ranges from about 60 down to 10 feet a day, slowing, of course, with depth. Thus, it is seen, to drill a well 3,000 feet deep might cost from $50,000 to $80,000 and require several months to complete. It is apparent, then, that oil-well drilling is a slow and costly process and makes a heavy draft upon the iron and steel industry, consuming, indeed, about one-twelfth of its output in ordinary times.

A well favorably located eventually penetrates an oil-bearing bed, and the petroleum may spurt forth in a lavish stream under the influence of the natural gas held in solution under pressure. Such wells are called gushers and some pour forth prodigious quantities of oil. Other wells flow with less violence, and many, lacking in notable quantities of natural gas, yield only under the inducement of pumping. All wells, however, soon reach a maximum production, after which they pass into a period of decline, and eventually become extinct. So inexorable is this procedure that a curve may be plotted in advance depicting the future behavior of a given group of wells. During decadence, wells are spurred into temporary renewals of activity by the explosion of charges of nitro-glycerine at their bottoms. The life of an oil-well varies from a few months to twenty years or more. The average life of Pennsylvania wells is estimated to be seven years.

When an oil-well becomes extinct, its non-productiveness does not signify that all the oil is exhausted. On the contrary, current practice in general leaves over half of the oil underground still clinging to the pores and capillary spaces in the rock. To obtain a greater yield from productive ground constitutes a problem of the first magnitude, and promising results have been obtained by forcing compressed air into some of the exhausted wells of a group, with the result that the laggard oil is swept to the neighborhood of other wells from which it may be pumped.

When a gusher is struck, adequate facilities are often lacking for catching and storing the product, so that veritable lakes of oil gather between quickly thrown-up embankments. Quantities, in such instances, are dissipated through seepage and evaporation, while disastrous fires of spectacular nature are not uncommon. With more careful development, however, field storage tanks shaped like huge cheese boxes are in readiness to receive the oil and prevent the glaring waste inherent in more hasty operations.

Turning attention from the single well to the oil-field, we observe that in petroleum mining sustained production depends upon an unbroken campaign of drilling operations. As an oil-field ages, new wells yield less than the initial yields of the earlier wells; hence a growing number of active wells is necessary to maintain production. Thus the producers must not only draw oil from existing wells, but at the same time must persist in the drilling of an increasing number of new wells and in the location of promising territory in advance of drilling. Any factor that retards any one of these three related activities quickly reacts to cause a falling off in production.

During 1920 approximately 33,400 oil-wells were completed in the United States, making the total number of producing wells at the close of that year about 260,000. As new wells are more productive than old wells, the cumulative requirements of new developments are strikingly apparent.

Output, development, and exploitation, therefore, must go hand in hand. In a general way, this threefold activity of production is carried on either as a large-scale engineering procedure or as a composite of small, individual operations. Large oil companies engaged in production naturally adopt what might be called the engineering procedure, while small companies and individual operators tend more to follow what is picturesquely termed "wildcat" operations. Thus the production of oil is in part dependent upon stable conditions, but in larger part is still a type of activity which approaches in considerable measure a gambling venture. This is why oil mining is generally looked upon and commonly described as hazardous from a financial point of view. The hazard is inherent only in small-scale operations.

The engineering type of production makes use of skilled geological knowledge in its campaign of oil production. The modern oil company employs a geologic staff, which determines by detailed field surveys the most promising spots for drilling. The implication, of course, is not that small companies do not employ geologic service, but, in general, the smaller the company the less likely it is to be capable of making the necessary expenditure. The Federal Government, through the United States Geological Survey, has rendered a signal service to the small operator by means of its published reports and maps covering oil regions, but the small operator has not in all instances taken advantage of even published geological information. The growth of oil geology has been rapid and while, of course, geologic science cannot strike oil with every drill, it multiplies by many times the possibilities of each drilling operation. It has been stated that "the operator who plays geology has a fifty times better chance of striking oil than he who does not."

But despite numerous highly organized production activities, the fact remains that the petroleum production of the United States is in considerable measure dependent upon a hit-or-miss plan of exploitation. Were it not for the wildcatter, who stakes his all (sometimes borrowed) on the chance that a random hole drilled in the general vicinity of productive territory will yield the hoped-for return, the output of petroleum in a country which produces two-thirds of the world's supply would fall to an utterly inadequate figure. The gambling instinct is still the prime motive power that lifts most of the oil produced in this country. Familiar is the saying, "Once an oil man, always an oil man."

The distinctive color of oil production can perhaps be effectively conveyed by means of a number of quotations culled here and there from current publications:

> The great army of men who produce our oil for us are in many cases of the rough-and-ready sort, but they are not penny-splitters and they are not hold-up men. Few of them have diplomas to exhibit, and their English may not be of the best; but they know how to do things with their hands, feet, and heads — and I do not believe that there is a more loyal or a more likable bunch of men in the world.
>
> . . . the producing branch of the industry . . . is a picturesque blending of temperament, personality, and psychology with all the mingled burlesque and common

sense that one would expect from unorganized energy and enthusiasm. Production is largely the outgrowth of the sporadic efforts of many "wildcatters" of many moods and varying capabilities.

Let us consider for a moment the vital question of drilling experimental wells—"wildcatting"—standing at the base of the discovery of new oil fields, without which the industry would dry up. For every field discovered there are hundreds—perhaps thousands—of experimental, worthless holes drilled—"wildcat" wells. The "wildcatter" is moved to take this long hazard, his big chance, his desperate gamble, through the highly speculative considerations surrounding his work—the hope of a great reward; realizing, however, all the time that the chances are ten to one against his success. . . .

The large producers and refineries, appreciating the value of the speculative oil seeker, foster rather than discourage his activities. He absolves them from considerable preliminary expense in drilling and proving a new territory. Their work is reduced to purchasing and transporting the raw material when it has been tapped. It is a development which is peculiar to the United States. In other oil-producing countries such a tendency is not supported.

It is the speculative character of the work that appeals to the American. He is a born gambler, delights in juggling with fortune; with him speculation is second nature. In the quest of oil he has unlimited capacity to gratify his desires to become rich quickly.

The mining of petroleum is notoriously wasteful. Under present practice, from 90 to 30 per cent. of the oil is left underground. Then, of the quantity produced, an appreciable percentage is lost by fire, and a significant portion dissipated by seepage and evaporation due to inadequate storage facilities. On the average, therefore, it is safe to say that less than 25 per cent. of the petroleum underground reaches the pipe-line. If we subtract from this proportion the losses involved in improper and wasteful methods of utilization, the recovery factor becomes perhaps as low as 10 per cent.

The Director of the Bureau of Mines writes in 1917:

> What effort have we made to conserve this supply and to utilize it to its greatest advantage? We have made little effort until very recently to do these things. We have been wasteful, careless, and recklessly ignorant. We have abandoned oil fields while a large part of the oil was still in the ground. We have allowed tremendous quantities of gas to waste in the air. We have let water into the oil sands, ruining areas that should have produced hundreds of thousands of barrels of oil. We lacked the knowledge to properly produce one needed product without overproducing products for which we have little need. We have used the most valuable parts of the oil for purposes to which the cheapest should have been devoted. For many years the gasoline fractions were practically a waste product during our quest for kerosene; with the development of the internal-combus-

tion engine the kerosene is now almost a waste product in our strenuous efforts to increase the yield of lighter distillates.

The two greatest wastes connected with oil-well drilling are caused by the harmful infiltration of water from water-bearing strata and the uncontrolled escape of natural gas encountered in the course of drilling. Water is a formidable enemy to oil extraction; as the position of the oil depends, in part, upon a nice equilibrium between oil and water, the undue influx of water into the drill hole means a reduced recovery of oil, if not a total loss of the well; and not only may a single well be completely ruined by inadequate protection against water, but—what is more grave—a whole field of operations may thereby be spoiled. The damage done in the past by water is immeasurable and largely irretrievable, but the danger from water may be controlled by means of a method of cementation already employed with success in California and Texas, whereby a watertight band of cement is forced into the space between the well casing and the water-bearing stratum.

Many wells in sinking penetrate gas-bearing formations, and in such instances it has usually been customary to suspend operations while the gas escaped into the air, so that the pressure might be relieved against which continued drilling was difficult or impossible. The actual waste of gas due to this circumstance has been first and last enormous, amounting to billions, if not trillions, of cubic feet, with a fuel equivalent of millions of tons of coal; indeed, it would be safe to say that of more than half the natural gas developed to date no use whatever has been made. But this physical waste, great as it has been, is of small consequence as compared with the waste of the energy represented by the gas pressure, the dissipation of which leads to a reduced and more difficult recovery of the oil. The gas, therefore, is not only substance but energy, and represents a force which must be conserved for the sake of later gaining a proper petroleum yield. It is rather interesting that the waste of oil and gas involved in the premature production of gas may be prevented by comparatively simple means; namely, by drilling in a medium of mud-laden fluid which serves to encrust the critical parts of the drill hole, sealing off the formation so that there is no improper escape of gas and preserving the conduit intact down to the productive stratum.

After the oil is struck, there are many methods for controlling the output so as to avoid the waste incidental to much of the current practice. The flow may be controlled by rather elaborate mechanical devices, preventing an overproduction; gushers "gone wild" may be capped and brought under subjugation; "blow-outs" may be guarded against and prevented; and losses due to fire, seepage, and evaporation largely nullified through adequate development of storage facilities. All these gains will accrue more fully through wide-spread application of well-known engineering technique already successfully practised in many instances.

The gas that almost invariably comes forth along with the oil customarily carries some of the lighter components of the oil itself. These components are recoverable, by means of appropriate methods, in the form of a very volatile gasoline, which can be blended with a heavier petroleum distillate to form commercial gasoline. Until a few years ago the recovery of the gasoline suspended in natural gas was neglected, but now a very significant yield of this so-called "casing-head" gasoline is obtained. The natural gas is made to yield up its gasoline either through compression, which squeezes out the liquid content, or by absorption, which entices it out by means of a certain type of oil which later is heated and thus forced to yield up in turn the gasoline absorbed. Even after full gasoline extraction, however, there remains in many fields much more gas than can be consumed by legitimate demand, which necessitates a waste of the surplus, unless it can be cheaply transported to points where demand exists.

Owing chiefly to the decline of pressure upon the escape of natural gas, wells quickly mature and then produce at a declining rate; but recent investigations go to show that even when a well is apparently exhausted, its full quota of oil has by no means been extracted. On the contrary, as demonstrated by established practice in Ohio and elsewhere, an additional yield may be forced by means of compressed air or its antithesis, a vacuum. The more promising of the two methods consists in forcing compressed air down to the porous oil-bearing formation, thus driving the oil to positions reached by pumping wells. The full possibilities of these methods may not be safely forecast, but they are certainly capable, if widely applied, of increasing by a large percentage the future yield of the country over the estimates made under current practice.

It would seem, then, that the wastes in connection with oil production, which are exceedingly heavy, are more due to inadequate utilization of technical knowledge than to lack of means for effecting the economy. To gain a greater return from the resource, therefore, is more a matter of shaping a proper economic situation in respect to its exploitation than it is a matter of technological research.

We have now observed in some detail the losses involved in the production of petroleum,—the oil left underground when the field is abandoned, the gas permitted to escape into the air or into barren formations, the destructive infiltration of water into the oil sands, the rapid production with demoralization of prices if the pool is large, the losses involved in storing the oil until it can be transported to market, the drilling of unnecessary wells, the inferior use to which much of the oil is put. These matters, of course, are well known and notorious. But they are manifestations merely. We must look deeper for the root causes that give rise to these wastes.

In the production of other raw materials there are no such conspicuous wastes as characterize the production of petroleum. There would appear to be, then, some fundamental factor peculiar to petroleum and conditioning the wasteful procedure common to its exploitation. This factor is not far to seek: it lies in the fact that petroleum is a migratory mineral and moves underground in the direction of decreased pressure. This factor, activated by unrestricted competition in production as commonly practised in the United States, is the fundamental cause of the wastes so preponderant with petroleum. Because petroleum is not fixed in position and much of the production, especially in young fields, is won through the efforts of small operators occupying small tracts, usually leased, there ensues a competitive scramble on the part of each operator to reach oil as quickly as possible and produce it as rapidly as possible. This means a ruthless sacrifice of all but the easy-to-get values. Even if an operator desires to defer production or restrain his output, as a rule he cannot do so because a rival operator with a neighboring well will suck from under his feet the oil which his lack of action relinquishes. So long as the ownership of oil is determined by vertical boundaries, arbitrarily dividing a geologic unit or reservoir into many portions, just so long will there be hurried production with all its train of losses. (See figures 17 and 18.)

Max W. Ball presented this situation very effectively in 1916 before the American Mining Congress in a paper entitled "Adequate Acreage and Oil Conservation," from which the following remarks are excerpted:

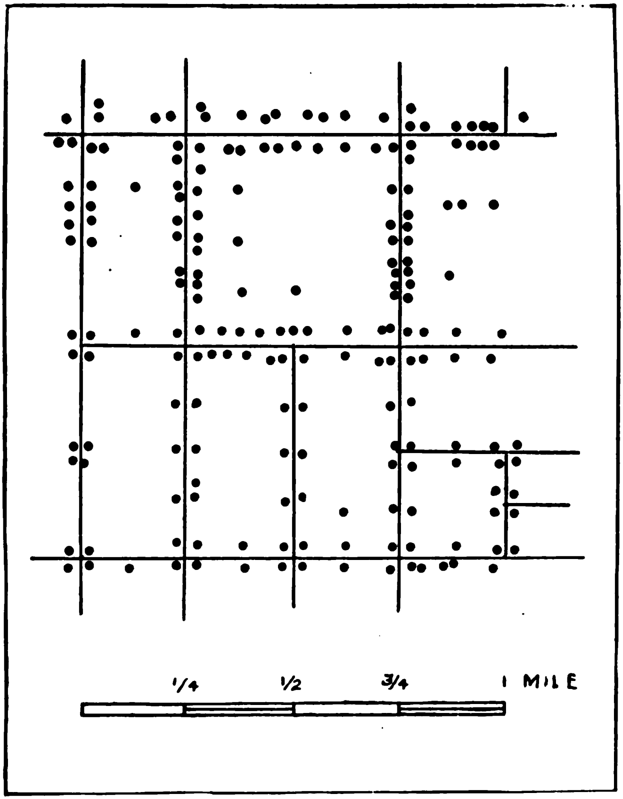


FIG. 17. Diagram showing the relation of oil-wells to property lines in a typical portion of the most productive light-oil field the world has seen, Cushing Pool, Oklahoma. (Note the small holdings, excessive number of wells, and the tendency of wells to occur in pairs on the opposite sides of property lines. This diagram epitomizes the fundamental cause of petroleum waste in the United States.)

There is the root of the whole trouble—the small holding. Let us go back over the history of the field.

We saw that as soon as the field was discovered it was leased up in small tracts. Then we saw the Smiths, the Browns, the Joneses, and the Standard Oil drilling for dear life, each trying to get the oil from under his little tract and a bit of the other fellow's before the other fellow could get it. Why? Because each tract was so small it could be drained by wells on the surrounding tracts.

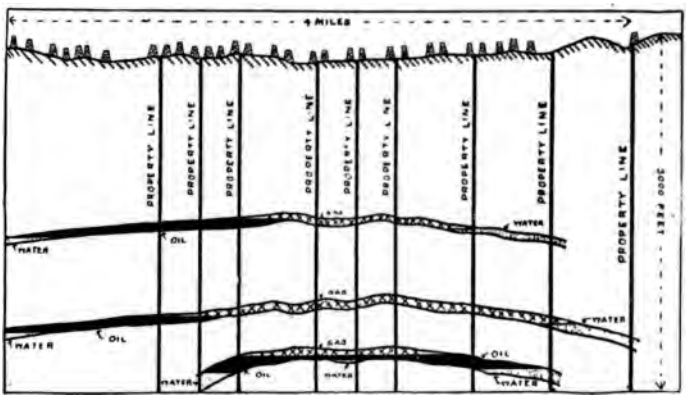


FIG. 18. Diagram showing the typical underground occurrence of oil, and gas, and water, and the customary discordant relations between property lines and geological occurrence. (The migratory character of oil renders this type of development unsound as leading to a racing and wasteful extraction of the oil. This diagram expresses the underground relations of the surface conditions depicted by Fig. 17.)

We saw that the race was so keen that wells were improperly drilled, that gas was allowed to waste into the air or dissipate itself through barren formations, that water was allowed to enter the oil sands, and that great quantities of oil were left underground, never to be recovered. Why? Because the small holding forced each man to race with his neighbor.

We saw the entire flush production of the field thrown on the market at once, demoralizing market prices, forcing the premature abandonment of wells in other fields, resulting in the burning of unrefined crude and the waste of the more valuable products. We saw the maximum production of the field go into storage, where the losses from evaporation and fire were enormous, and where the cost of the oil was nearly doubled. What caused these things? The fact that every holder of a small lease must drill it up as soon as possible.

Lastly, we saw the cost of production more than 300 per cent. what it should have been. And what was the reason? That every man must drill his lines as fast as might be, and must completely drill up his land at the earliest moment. Why? Because the oil under his small holding could be taken from him by wells on surrounding tracts.

Ignorance there may be, carelessness there undoubtedly is, but back of ignorance, of carelessness, of reckless, headlong methods, is the real cause—the fact that the average holding is so small that speed is the owner's sole protection. Let him be careful if he can; let him be economical if he can find a way; but careful or careless, reckless or conservative, he must be speedy if he would survive. The small holding is his master.

The headlong, and consequently extremely wasteful, production of oil is greatly facilitated by further circumstances. The gambling character of wildcat drilling in itself leads to the desire for quick returns, with little regard to the niceties of engineering efficiency. Then, the automatic character of production, once the oil is reached, attaches small cost to the actual production; not infrequently, in fact, it costs more to retard the output than to produce at maximum speed. Thus an incentive is lacking for exercising care with a product gained easily and oftimes lavishly. There is, also, virtually an unlimited demand for cheap petroleum for inferior uses, affording a convenient outlet for hasty production and tending to support the grossest overproduction with at least a modicum of profit.

Accordingly, because the cost of production is slight, wastes in production are of little consequence to the producer; while, owing to the competitive race for extraction, production is unrestrained. Thus oil is produced with no adjustment to the legitimate (that is, high-use) demand, which gives a surplus of cheap oil that takes advantage of and encourages the ever present latent demand for fuel oil.

This may appear to be an exaggerated account of petroleum production. But such are the motives and conditions that prompt the production of the major part of the output of the United States and hence dominate the situation. With increasing scope of organization in production, of course, these conditions tend to modify. With broadly integrated operations, production may escape entirely the influence of the factors noted. But, by and large, it costs a good deal to reach oil, but little to produce it, at least during the flush period. When reached, the oil must be produced as rapidly as possible, or some one else will get it. There is an unlimited demand for the crude product for fuel purposes, with profit in such sale. In brief, the free operation of the law of supply and demand under continuation of small-unit competition in oil production is forcing the sacrifice of the greater part of our most essential and most limited resource.

Production and consumption, of course, cannot coincide in quantity; hence, of necessity, there are reserves of petroleum above-ground which serve as an expansion and contraction joint, so to speak, between supply and demand. When there is an overproduction in respect to current needs, the reserves or, as commonly stated, the stocks increase; conversely, with industrial expansion or lessened output, drafts are made upon the stocks, which then decrease. The condition of the stocks, therefore, is a sort of pulse to the crude-oil market, since prices, under the influence of the same factor of supply and demand, fluctuate in like manner. During the past few years the quantity of crude petroleum in storage in the United States, while not changing greatly in volume, has in a relative sense because of increased consumption shrunk from a six months' supply to a quantity capable of sustaining the country only three months if exclusively drawn upon.

The price of crude petroleum at the well varies considerably according to quality, distance from market, and other factors. The paraffin oils of light gravity, such as those produced in Pennsylvania, are the most valuable because they yield the largest percentage of products in demand, while the asphaltic oils of heavy gravity, such as those of California and part of the Gulf region, command a price roughly a fourth of that which the best quality oil enjoys. Thus Pennsylvania crude petroleum began 1915 with a price of about $1.45 a barrel and ended 1920 at $6.10, while during the same period California crude climbed from about 37½ cents to $1.60. These two types of oil represent the extremes of quality, with the factor of distance from markets nearly the same in the two instances. Between these limits range the prices of all the other oils of the country, the quotation at any given time and location being a complex of quality and of balance between supply and demand, with all the qualifications that the latter expression involves. The wide range in prices for a single raw material, with the utmost concession to differences in location and composition, suggests an undue discrepancy to be credited against the conditions under which oil is produced.

The dependence of sustained production upon an unbroken campaign of drilling exploration, and the extent to which such a campaign is carried on by "wildcat" operations on the part of small companies and individuals, leads to many perplexing legal and economic difficulties. Land, of course, is rarely owned by the operator, so that he must ordinarily either purchase or lease the oil (and gas) right. The laws connected with oil lands have not been modernized, but are confusing and in part conflicting, so that the operator is put to undue trouble and expense in meeting the legal requirements of his holdings. Moreover, the method of leasing under small-unit operations leads to a wasteful competition between neighboring wells in their race to secure a maximum production within the period of the lease,—haste, with waste, being an economic necessity in such instances. In 1920, after ten years of agitating, an oil-land leasing act, opening to development some six million acres of withdrawn oil lands chiefly in Wyoming and California, was passed by Congress. This action did not enlarge the oil resources of the United States, but merely made a small portion more quickly available.

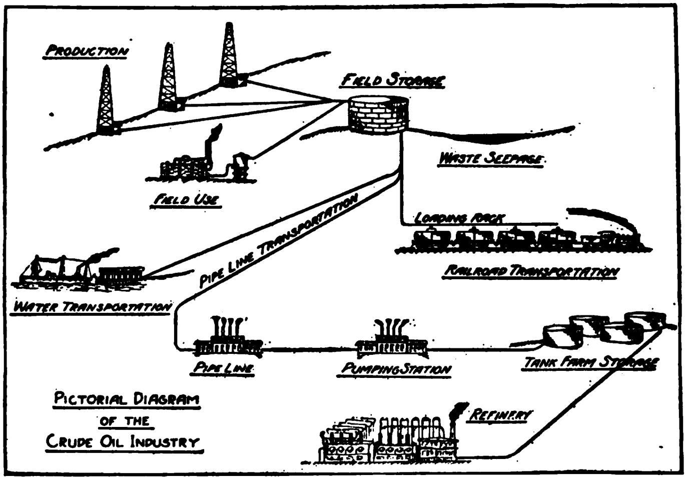
One of the remarkable and impressive features of the petroleum industry is the fact that the crude product is transported through a system of pipelines that connects the points of production with refineries, markets, and seaports. This method of handling is natural and inevitable with a liquid product consumed in bulk, as evidenced by a somewhat analogous method of transportation adopted for municipal water-supply. While petroleum shares with coal the main responsibility for energizing the mechanical activities of the country, it is interesting to note that crude oil, unlike raw coal, imposes normally no appreciable burden upon the railways.

The pipe-lines of the United States, comprising those of the subsidiary companies of the Standard Oil and a number of independent companies, aggregate thousands of miles in length and form a network spread over much of the country. They consist of trunk-lines, the longest of which connects Oklahoma with the Atlantic seaboard by way of Illinois, and gathering lines leading into the main channels. The whole system is comparable to the arteries and veins of the human body.

The pipes vary in diameter from two to twelve inches, but six to ten inches represent the common sizes. The piping is made of iron plate and is ordinarily placed below the surface of the ground. At intervals of from fifteen to thirty miles, according to the viscosity of the oil, are pumping stations, where powerful pumps seize the spent oil and force it forward with renewed vigor. In the case of heavy, viscous oils, such as those of California, it becomes necessary to heat the product at each pumping station to facilitate its progress. Unlike a railway, the pipe-lines in general follow a direct course, up hill and down. The pipe-line facilities of the country are ample to handle the normal distribution of the current production.

The significance of the pipe-line in the development of the petroleum industry has been great. It has made crude petroleum independent of the railways,—a very important matter, bringing up an obvious comparison with coal, which needs, in part at least, a like emancipation,—and through cheapness of operation has lowered the cost of petroleum products; it has freed the refineries from geographic allegiance to areas of production and permitted their establishment at strategic points in respect to consumption of products; it has permitted and induced integration of activities, with marked advantage to the consuming public, but not unaccompanied by hardships and abuses falling upon small units of the industry itself; and by stretching out to meet a growing area of exploitation it has unified widely separated fields and enabled production to grow to its present imposing size. The pipe-line has drawn the scattered units of adventurous exploration into a steady flow of bulk raw material. (See figure 19.)

Some crude petroleum is transported in tank-cars, but most of the sixty thousand tank-cars in operation in this country are engaged in moving petroleum products,—chiefly gasoline, kerosene, and fuel oil. For transportation by sea, steel tankers and towing barges, fitted with non-communicating compartments, are employed for both crude petroleum and its bulk products. The tanker is the only commercial rival to the pipe-line; movements of oil from the Gulf to north Atlantic ports, therefore, normally go coastwise instead of overland. The development of the tank-steamer has been an important factor in building up an important foreign trade in petroleum products, is responsible for a considerable coastwise movement of crude and fuel oil, and has opened the oil-fields of Mexico to the United States and other markets.

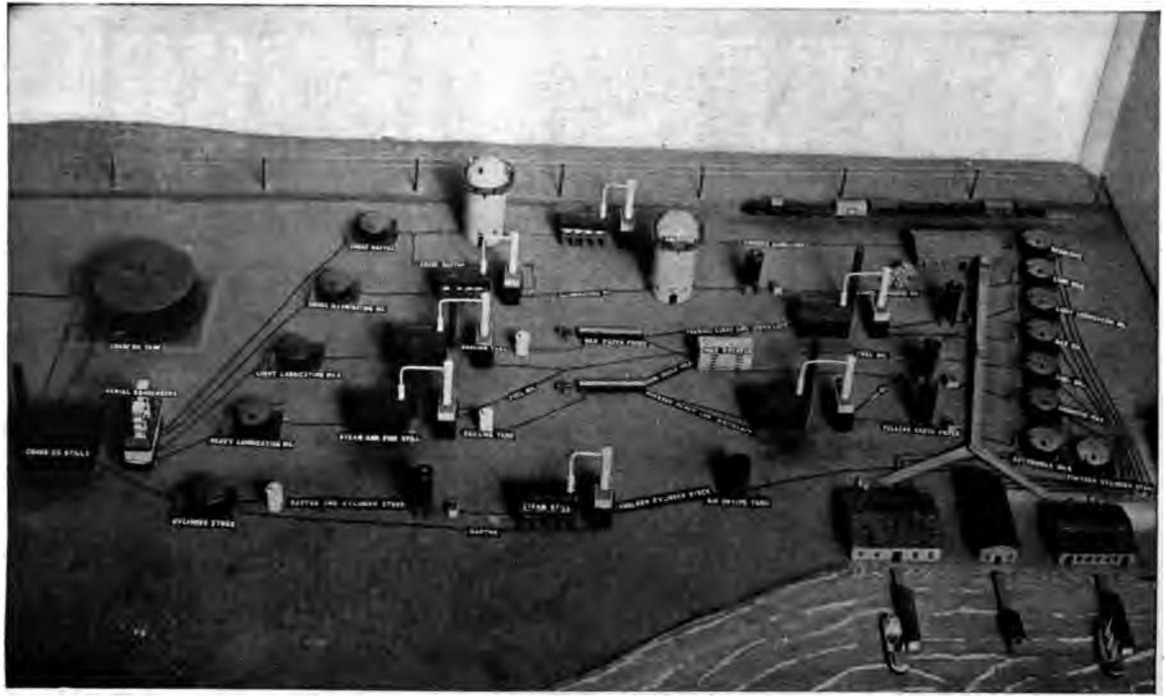


(From California State Council of Defense.)
FIG. 19. Diagrammatic view of the oil industry.

Crude petroleum may be burned as fuel and a small quantity of the domestic consumption is utilized in this way. But most of the petroleum is manufactured into a series of products which have wider usefulness and higher value than the crude oil, and it is upon this dominant part that the petroleum-refining industry depends. The refinery is merely an ingenious mechanical device whereby the raw material, through the agency of physics and chemistry, is fitted into the needs of society. (See figure 20.) As these needs are ever increasing in size and diversity, the refining practice is in continuous flux, adapting a definite substance to a shifting and widening demand.

At the present time petroleum yields, when completely refined, four main products—gasoline, kerosene, fuel oil, and lubricating oil—and a large number of by-products, of which benzine, vaseline, paraffin, road oil, asphalt, and petroleum coke are well-known examples. (See figure 21.) Most of these products in turn may be broken up into other substances, each the starting-point of further refinements. Under present practice petroleum yields only a few hundred substances of commercial value, but the mind can set absolutely no limit to the number of useful materials that chemical research may still wrest from this raw material.

While refinery practice is a highly technical matter and varies both according to the chemical nature of the oil and the local demand for products, we may, for the sake of simplicity, ignore



(Photograph of an idealized model in the Division of Mineral Technology, U. S. National Museum.)
FIG. 20. A petroleum refinery.

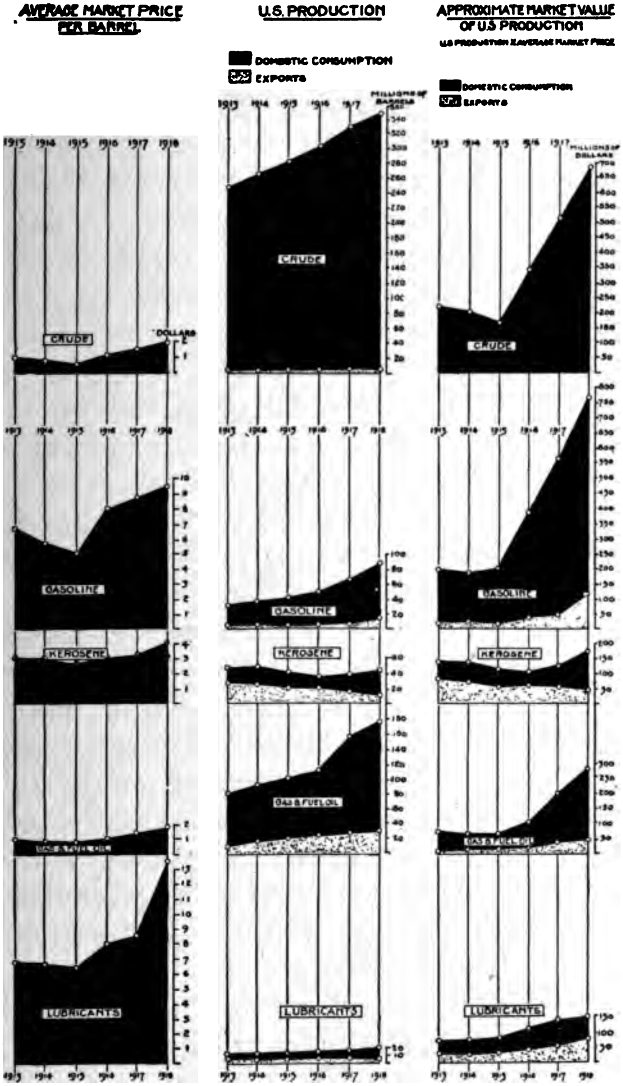


FIG. 21. The price and value relationships of the petroleum industry, 1913–18.

all details, and note merely that there are three main types of refineries. The first of these is called a "skimming" or "topping" plant, because the light oils gasoline and kerosene are removed from the rest of the products, which are left behind as a residual oil and sold in this semicrude condition for fuel purposes. The "skimming" plant, as its name implies, makes an incomplete recovery of products, supplying only those in greatest demand or easiest to make; many of the plants of this kind are situated west of the Mississippi River.

The second type of refinery may be termed the "straight-run" plant; this produces all four of the main products,—gasoline, kerosene, fuel oil, and lubricating oil,—together with by-products, the process separating the crude oil into its natural components with the minimum of chemical change. The "straight-run" refinery lacks flexibility, because it has no power of producing, for example, more gasoline than the crude oil naturally contains. Such plants are situated in the East and other parts of the country where the demand, especially for lubricants, justifies the expense of the practice.

The third type of refinery is of recent birth, but has made rapid strides toward a great future; it employs the so-called "cracking" process, which yields, like the "straight-run" plant, a full set of products, but a greater percentage of gasoline than the crude oil yields upon ordinary distillation. This is accomplished at the expense of the heavier component oils, whose molecules are broken or "cracked" into lighter molecules, which constitute just so much additional gasoline. It is obvious that cracking has developed in response to a growing demand for gasoline; its significance is apparent in the fact that it permits the production of a more valuable product from one less valuable. With an increasing call for gasoline and a decreasing supply of petroleum, cracking may be expected to come into growing prominence.

If we pause for a moment to contemplate the consumption of petroleum in the crude condition, and then the three types of refining—skimming, straight-run, and cracking—it becomes evident that each treatment represents a step in advance over the preceding, and that, while all three prevail to-day, the cracking refinery is in line with true progress and will eventually dominate the situation.

Refineries, whatever the type, employ the principle of distillation in their operations. The petroleum is heated in stills and the products vaporize, pass off, and are condensed in fractions representing roughly the materials in demand. These products are then purified by chemical treatment or transformed by chemical means into a series of secondary products. The production of the various kinds of lubricating oils needed for diverse uses represents an intricate, yet single, part of petroleum refining; and is merely one aspect of the many ramifications found in refinery technique. The refining of petroleum makes heavy drafts upon other chemical industries (for example, in normal times, about one tenth of the sulphuric acid produced in the United States goes into petroleum refining), but the refinery in turn contributes many essential products to other chemical manufacturing activities. These industrial interrelationships, ofttimes overlooked, are of the utmost significance,—a fact strikingly brought out when one activity is called upon to expand more rapidly than some other activity with which it is geared.

The refining of petroleum, requiring elaborate plants, is by nature a large-scale enterprise; hence, such activities in the main have naturally come under the control of a few large organizations. While several hundred individual refineries are in operation, the bulk of the output is due to the efforts of less than ten companies. The refining of petroleum, therefore, is largely an integrated activity, in close alliance with transportation of crude petroleum, on the one hand, and distribution of refined products on the other. It has already been pointed out that the development of pipe-line transportation has permitted the establishment of refineries at points distant from oil-fields but convenient to centers of consumption and to seaports. Hence, one of the largest refineries in the world is at Bayonne, New Jersey, consuming oil from the interior of the country.

With the broad outlines of refinery technique in mind, it will be of interest to observe the shifting focus of development that has characterized the production of petroleum products in America. When the famous Drake well struck oil on Oil Creek, Pennsylvania, in 1859, an illuminating oil distilled from coal and called "coal-oil" was in general use throughout the country. Petroleum, therefore, found a market already established for its illuminating constituent, which it usurped at once, quickly supplanting the coal-oil industry with a production of kerosene. Although other products were also produced and lubricating oils made from petroleum found quick favor in connection with a growing application of mechanical energy, kerosene became the chief petroleum product and for over forty years its use expanded until this illuminant penetrated literally to the uttermost corners of the globe. It would be difficult, indeed, to estimate the value to the world at large of this cheap and convenient source of light, which has been aptly termed "one of the greatest of all modern agents of civilization." During this period there was little demand for the light products of distillation, the liquids now sold under the commercial name of gasoline, which were therefore largely waste products in an economic sense and even in some instances physically destroyed for want of any adequate demand for their utilization. Gasoline for a long time, then, was a by-product of little value turned out in the manufacture of kerosene. (See figure 22.)

Toward the close of the nineteenth century, however, the commercial application of the incandescent mantle in gas-lighting and the development of the electric light introduced a type of illumination so superior to the kerosene lamp in convenience that the use of the latter was gradually relegated in large part to the small town, the country, and foreign regions, where the introduction of gas and electricity was not possible. Accordingly, despite a most aggressive campaign

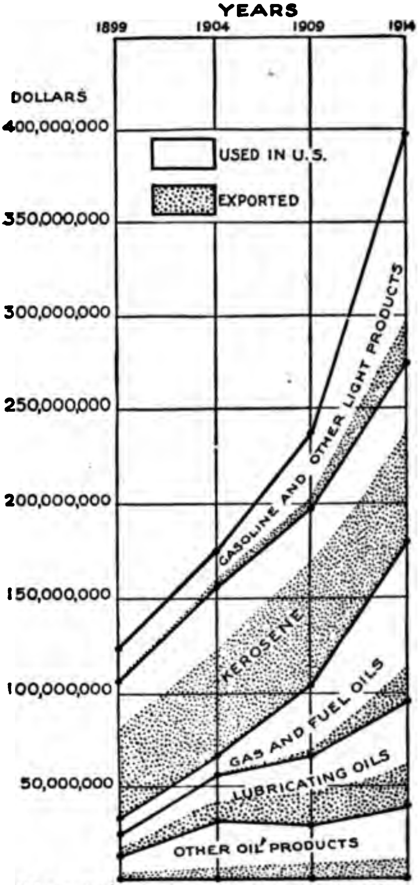


Fig. 22. The relative values of the principal petroleum products manufactured in the United States from 1899–1914. (The estimated value of the petroleum products manufactured in 1920 is three billion dollars.)

for foreign trade on the part of the petroleum industry, the refinery faced the restrictions of a slowing demand for kerosene which presaged a limit to the output of the whole set of petroleum products. But the menace of this limiting circumstance was destroyed, before it became effective, by the introduction and rapid advance of the internal-combustion engine. The phenomenal growth in the use of the automobile built up such a heavy demand for gasoline that this product came into the lead and took up the burden of justifying the increasing refinery consumption of crude petroleum,—a burden which kerosene, even with the aid of a growing market for fuel oil, lubricants, and other oil products, was scarcely longer able to sustain. Gasoline became the main prop to the whole cost structure of petroleum refining.

With the industrial quickening due to the entrance of the United States into the World War, the demand for fuel oil, accentuated by the coal famine of 1917–18, became so insistent that the complexion of the oil situation changed. For the time being, fuel oil took the lead and set the pace in the economics of the situation; gasoline became of secondary importance. But the dominance of fuel oil was short-lived. As soon as the war ended, the demand for fuel oil appreciably slackened, creating a surplus of this product and shifting the emphasis back to the shoulders of gasoline. Now the call for motor fuel is growing so rapidly that a serious question is raised as to whether the supply of gasoline will be able to keep pace. So insistent, indeed, is the prospective demand for motor fuel, that it is probable that eventually all the petroleum products now burned as ordinary fuel will be used in internal-combustion engines.

If the course of development, as indicated by this broad survey of refinery evolution, be projected into the future, we may foresee a time when the petroleum industry will yield a range of fuels for the internal-combustion engine only; illuminating kerosene in quantity narrowing to that desirable for country use and export trade; lubricating oils adjusted to the growing demands of mechanical power; and an ever widening range of chemical products supporting a great oil by-products industry, rivaling if not exceeding the coal-products industry in importance. In respect to the last, it should be emphasized that the United States to-day faces an opportunity similar to that which twenty years ago confronted both Germany and the United States as regards the manufacture of dyestuffs, explosives, fertilizers, drugs, and other chemicals from the non-fuel components of coal.

Many industries terminate their activities with the manufacture of commercial products, turning these over to independent agencies for distribution. With the petroleum industry, however, distribution forms an integral division of the industrial activity, a carefully planned out construction of markets as part of the resource development being substituted for a demand ordinarily left to natural growth or maintained by costly advertising. Thus, once the oil is produced, it passes through the various stages of transportation, refining, and distribution under the influence of a highly organized economic machine, a coördinated industrial unit, engaged not merely in adapting a crude material to diverse uses, but also in shaping and developing latent needs the world over into a demand which will sustain a balanced output of products.

We have already seen how the pipe-line, and to a less extent the coastwise tanker, brings the crude petroleum to the refineries which are favorably located in respect to distribution. From the refineries the gasoline, kerosene, fuel oil, lubricating oil, and other petroleum products are sent forth to supply the needs of surrounding territory, while refineries near the seaboard furnish heavy contributions to foreign trade. As distribution is a diverging process, and moreover, the crude petroleum is converted into numerous products requiring separate handling, the pipe-line is not broadly adapted to this diverse haulage. Railway tank-cars, therefore, receive the bulkier products and carry them to distributing depots, where storage tanks release the railway carriers and supply tank-wagons that radiate to fill the local needs. In this way the entire country is covered by a network of specialized transportation, each step employing a bulk carrier best adapted to its particular purpose both as to size and mechanical facility, the whole involving the maximum of expedition and simplicity. Without this highly organized system, with its far-reaching ramifications, the present wide-spread use of gasoline and kerosene would not be possible.

The arrangements whereby a foreign trade has been built up and sustained are no less elaborate. Fleets of tank-steamers and freighters carry the products in bulk or in suitable containers to all parts of the world. Fuel oil, gasoline, and lubricants go in greater measure to industrial countries, but kerosene penetrates to every corner of the globe, a system of depots and distributing lines adapting the product to the needs of the most out-of-the-way regions. The care that has been bestowed upon the extensions of the market for kerosene, against every conceivable obstacle of climate, topography, and racial prejudice, is a striking example of industrial foresight; and without this policy, the whole oil industry would have been unable to expand to its present proportions.

CHAPTER V

NATURAL GAS, NATURE'S BONUS TO AMERICA

NATURAL gas is produced in large quantities in the United States, partly as a by-product from oil-wells but chiefly from gas-wells drilled in oil-fields or adjacent territory. Both natural gas and petroleum are of common origin,—the former, indeed, being merely a volatile component of petroleum, occurring dissolved in the petroleum under pressure or else migrated, as a result of the advantageous degree of mobility favoring a gas, to positions more or less distant from the oil. The gas-bearing territory of the United States, therefore, embraces the productive oil-fields and a considerable area besides. Natural gas is won in twenty-three states, but 98 per cent. of the total supply comes from West Virginia, Pennsylvania, Oklahoma, Ohio, Louisiana, Kansas, California, Texas, and New York. The most productive state is West Virginia, which alone is responsible for about 40 per cent. of the total.

The magnitude of the service rendered by natural gas is not generally appreciated. The annual production of the country in 1917 was about 800,000,000,000 cubic feet,—three quarters of all the gas sold,—but since that time the production has been rapidly declining, with an estimated production in 1920 of less than 650,000,000,000 cubic feet. Half the towns served by gas enjoy the privilege of nature's product, which is more freely used when available than manufactured gas because of its greater cheapness. There are over 2,000,000 domestic consumers of natural gas, which means that a tenth of our population is partly to wholly dependent upon this product for lighting, cooking, and heating. It is a serious matter when the production of an essential commodity serving directly so large a share of the population has entered upon a waning course.

Although natural gas is the ideal fuel for the American home, because of its convenience, cleanliness, and cheapness in regions so fortunate as to be endowed with this product, most of the supply is not devoted to domestic use but is consumed for industrial purposes. About two thirds of the total output of the United States, in fact, is burned in manufacturing plants under steam-boilers, or consumed in metallurgical operations, glass and pottery furnaces, and cement kilns, where the requirements of an intense heat call for gaseous fuel. In Ohio and western Pennsylvania, in particular, the abundant occurrence of natural gas has determined the location and wide-spread development of gas-fired industries. Thus Ohio and Pennsylvania are the two leading states in the manufacture of clay products; the Pittsburgh district is the greatest glass-manufacturing district of the United States; while the iron and steel industry in the vicinity of Pittsburgh consumes an enormous volume of natural gas in its blast-furnaces, foundries, and rolling-mills. Natural gas has been "the fourth element in making western Pennsylvania more liberally supplied with fuel than any other place in the world. In that region a thick forest covered hills which were underlain with the magnificent coal deposits of the Appalachian field, while farther down was the crude petroleum and the natural gas that drove it spurting from the orifices in the rocks." The rising cost of natural gas, coming with progressive exhaustion of fields, has caused a migration in the glass-making industry, many plants having moved from Pennsylvania to West Virginia and from Indiana to Oklahoma in order to get cheaper fuel; other plants in regions declining in natural-gas yield have turned to producer gas made from coal, a less satisfactory fuel because not so high in heat value. The manufacture of carbon black, or lampblack, used in pigments, is an industry largely confined to West Virginia, where in 1915 from 19,000,000,000 cubic feet of natural gas there was manufactured 17,000,000 pounds of carbon black, the gas for this purpose having an estimated average value of 2.34 cents per 1000 cubic feet.

The commercial importance of natural gas in comparison with the other fuels in common use, is shown in the following table:

RELATIVE COMMERCIAL IMPORTANCE OF NATURAL GAS, EXPRESSED ON A PER-CAPITA BASIS FOR 1918[a]

	Consumption per capita	Value per capita	Average price
Natural gas (cu. ft.)	6386	$1.60	[c] $0.25
Artificial city gas (cu ft.)	[b] 2321	2.12	[c] .91
By-product, coke-oven gas (cu. ft.)	1584	.14	[c] .09
Crude petroleum (barrels)	3.6	7.04	1.98
Anthracite coal (tons)	.98	3.36	[d] 3.40
Bituminous coal (tons)	5.8	14.92	[d] 2.58

[a] Figures calculated on basis of population of 100.000,000 from data published in Mineral Resources of the United States in 1919, U. S. Geological Survey.

[b] Includes various types of artificial gas as commonly supplied in municipalities.

[c] Per 1000 cubic feet. Note the marked discrepancy in price per 1000 cubic feet. The intrinsic value, as contrasted with the commercial value, is 1.5-2, 1, and 1 respectively.

[d] Price at mines.

The natural gas produced is of two types, according to whether it carries a conspicuous burden of gasoline vapor or is lean in this constituent. The first type, as may be surmised, flows from an oil-productive stratum and is called "wet" or casing-head gas, since it makes its appearance from the casing heads of oil-wells. The second type is termed "dry" gas, and comes from portions of porous rock formations virtually free of oil; it is produced through gas-wells more or less independently of petroleum output.

While the production of gasoline from natural gas has been largely confined to casing-head gas, because of its relative richness in gasoline vapor, the recent development of absorption processes extends the possibility to the bulk of the "dry" gas produced. It is conservatively estimated that a gasoline production of one hundred million gallons a year could be attained in this manner, and a significant start has already been made.

Those activities concerned with the production, transportation, and marketing of natural gas constitute the natural-gas industry. It is largely independent of the petroleum industry, although partly overlapping in production. It consists, in the main, of a large number of independent companies in the form of public-service corporations dealing exclusively with gas, although some oil companies market their surplus gas. The drilling of gas-wells is not essentially different from that of oil-wells; but gas, unlike oil, cannot be stored in the field and hence is piped directly to centers of consumption.

Natural gas occurs not in underground caves, as is popularly supposed, but in porous rocks such as sandstones, occupying the millions of microscopic cavities between the grains of the rock. Confined in positions under-ground by surrounding layers of impervious rock, through which it cannot pass, natural gas is at rest until reached by the drill hole, when urged by its expansive nature it seeks access to the surface. It is prevented from escaping into overlying porous formations by iron tubing—called casing—which lines the drill hole down to the productive stratum. When it reaches the surface, the gas is under a natural pressure, varying according to localities, but usually several hundred pounds per square inch; from the casing head the gas is conducted through iron piping, ofttimes hundreds of miles, to the points of consumption. The natural pressure of the gas may be sufficient to force the product short distances, but for distant transmission the gas must be recompressed in stations equipped with elaborate machinery for the purpose. Compressor stations ultimately become necessary even for short-distance transmission, for the natural pressure of gas-wells declines as more and more of the gas is removed from the underground reservoir. (See figure 23).

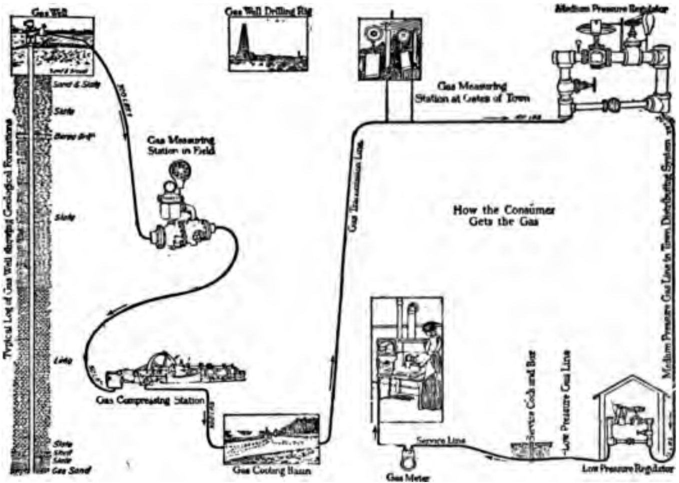

Gas Well
Gas Well Drilling Rig
Typical Log of Gas Well showing Geological Formations
Sand & Slate
Slate
Slate
Lime
Slate
Shell
Slate
Gas Sand
Gas Measuring Station in Field
Gas Compressing Station
Gas Cooling Basin
Gas Transmission Line
Gas Measuring Station at Gates of Town
Medium Pressure Regulator
How the Consumer Gets the Gas
Medium Pressure Gas Line to Town Distributing System
Service Cock and Box
Low Pressure Gas Line
Service Line
Gas Meter
Low Pressure Regulator

FIG. 23. Diagrammatic view of the natural-gas industry. (After Wyer.)

As a gas-well becomes extinct in comparatively a few years, the maintenance of a sustained flow of gas necessitates a continuous program of drilling so that new wells may be brought in as old wells decline. The necessity for continuous development work, the erection of compressor stations, and the maintenance of hundreds of miles of transmission piping together with stations for recording and regulating the flow of gas, render natural-gas service a large-scale enterprise requiring considerable outlay and expert attention for adequate operation.

While the United States has been endowed with a lavish supply of natural gas,—an asset enjoyed in like degree by no other nation,—the resource has been so extravagantly and wastefully exploited that the supply has already run short in many parts of the country and the utmost care is necessary that regions still enjoying natural-gas service may not be prematurely cut off from this advantage. A poster spread broadcast during the war by the United States Fuel Administration reads as follows:

> Natural gas is becoming scarce; the demands for natural gas are now greater than the available supply. When the present supplies are exhausted we must go back to the more expensive and inferior manufactured gas. The use of natural gas is not an inalienable right, but a privilege enjoyed by about 10 per cent. of our entire population in the United States, and used in a most extravagant and wasteful manner with no regard for the future, and not appreciated until it is gone.

The history of the natural-gas industry of the United States "is an appalling record of incredible waste.'' The annual reports of the Conservation Committee of the Natural Gas Association of America ''are stinging indictments of a criminal system, fostered by both the gas companies and the public, that has resulted in wasting more gas than has ever been utilized.'' Samuel S. Wyer of the Fuel Administration estimated in 1918, that the annual wastage of natural gas in the United States was equal to the current consumption,—that is, 800,000,000,000 cubic feet. At 30 cents a thousand cubic feet this annual loss would be appraised at $240,000,000; but inasmuch as natural gas wasted is gone forever, it is fairer to compute the loss on the basis that 1,200,000,000,000 cubic feet of manufactured gas would be necessary to replace the waste of natural gas, and the necesary substitute at prevailing rates would cost $1,200,000,000. The contemplation of such figures is staggering to the imagination. It is estimated on good engineering authority that the two million housekeepers in the United States who use natural gas could save at least $36,000,000 worth of gas annually if their cooking appliances were properly adjusted.

These amazing wastes are serious enough as sheer physical losses. They assume added importance from the fact that many towns in the country are now having to turn from cheap natural gas to expensive manufactured gas. In short, the waste of natural gas does not concern future generations; these losses are being paid for to-day. In no direction is conservation more critically needed, nor more promising of such immediate returns, as in the realm of natural gas. In a few short months in 1918, the Bureau of Oil Conservation of the Fuel Administration effected economies which resulted in the saving of millions of dollars' worth of this valuable fuel, but with the coming of peace this valuable work, undertaken as a war measure, was terminated.

It would be a matter of too great tedium to detail the manifold ways in which natural gas is lost in its devious course from a position underground to the hands of the consumer. Back of the whole train of losses, as in the case of oil, lies an economic situation working at cross purposes with the natural occurrence of the product. As a result of its underground disposition, gas is fixed in position only so long as it is not disturbed by external agencies. A single drill hole will upset the delicate equilibrium that exists and gas from far and wide will seek any available outlet to the surface. In consequence the projection of surface boundaries between properties down into a gas reservoir—the method of apportionment recognized by law—pretends to divide a resource in a manner in which it cannot be divided. The result is the same as though one sought to divide a pitcher of water with a cake knife. Unfortunately for efficiency, most occurrences of gas underlie surface properties owned by various individuals. The virtual outcome of this practice of handling gas as if it were a solid is a situation where such owners race with one another to extract the maximum supply. No party to the undertaking can delay; he who does loses. Only where large companies acquire the gas rights over an entire unit of occurrence can gas be efficiently produced. The individualistic production of natural gas leads to hasty, wasteful mining and to an output in advance of true needs which creates a surplus seeking an outlet at whatever price it will bring.

Competition in a gas field always results in a duplication of lines, unnecessary wells, enhanced operating cost, lack of proper coördination, failure to remove all the gas, and shortened life of the field, with the inevitable resulting injury to the domestic consumer. Under competitive conditions, even when the underground gas reservoir is made up of many local pools, various operators will drill into the same local pool, and thus drain out the gas from under each other's leaseholds.

After the gas is produced, much escapes into the atmosphere, both in the field and in course of transmission to the consumer. When oil and gas are found in the same well, it is common practice to blow the gas into the air in order to obtain the oil, which is more valuable. Especially in fields distant from markets, there has been little incentive to bother with the gas, which has been largely looked upon and treated as a waste product, although now known to be necessary to the proper recovery of the oil. By means of mud-laden fluid, the gas-bearing beds encountered by the oil-seeking drill may be sealed off and the gas conserved for the protection of the oil beds and for subsequent recovery. The gas flowing from the oil-productive stratum along with the oil is the casing-head gas from which since 1910 a growing production of gasoline has been won. The lack of coördinated production of gas and oil, where the two occur jointly, is responsible for probably a greater loss of gas than all other causes together.

Because natural gas lacks color and odor, leaks in transmission and distributing lines are not readily detected and are responsible for inordinate losses. This is true of many of the large natural-gas companies which make a point of efficiency in production. Owing to the fact that adequate measuring devices for recording the quantity of gas taken in at one end of the line and that delivered at the other end are frequently lacking, gas leaks may go for long periods undetected. It has also been recently demonstrated that stray electric currents from trolley lines have a strong corrosive tendency on the gas-pipes in their path; this source of waste is not yet generally appreciated and bids fair to become even more serious in the future, if protective measures are not developed. Even after the gas passes the meter in the consumer's house, leakage takes place to a surprising extent. In a number of houses checked for leakage, it has been found that losses on this score averaged 19,000 cubic feet per year for each house.

But the story of waste is not finished when the gas enters into consumption. Flat rates for the year, instead of metered service; free gas supplied as inducements to factories; improper appliances for burning the gas; carelessness—all these are party to criminal losses. The outstanding cause of wastes in utilization is the cheapness of the product, a cheapness out of all proportion to the intrinsic worth of natural gas. For example, in 1915, the average price of natural gas to industrial users was 10 cents per thousand cubic feet, while domestic consumers paid 28 cents, although 91 cents was the average rate charged for artificial city gas scarcely half as good. This enormous discrepancy in the cost of gaseous fuel in regions enjoying natural gas as contrasted with those in which manufactured gas must be supplied is the crux of the whole gas situation. Although the cost of artificial gas is undoubtedly much higher than it need be under a system of efficient, coordinated production, the fact remains that natural gas does not have its proper valuation when its nearest analogue and successor costs about ten times as much. It would be difficult to persuade the average domestic consumer of natural gas that he would save in the end if natural gas were not so cheap, but the conclusion is unescapable that the resource is being prematurely depleted because at present rates adequate care in production cannot be afforded and the bulk use of natural gas in all sorts of industrial uses is supported. The question is whether we shall have cheap natural gas for a brief period, or moderately priced natural gas for a longer time. That question, unfortunately, is no longer open to thousands of consumers, who can no longer get natural gas at any price. And the number of those thrown back on expensive manufactured gas is increasing yearly.

There are many other problems connected with natural gas that can only be touched upon here. The manufacture of carbon black, used in paints, is one of these problems. About twenty-six billion cubic feet of natural gas is annually devoted to this purpose. The process of manufacture consists merely of burning the gas so that the flame impinges against a metal plate; the soot deposited upon this plate is scraped off from time to time and constitutes the carbon black of commerce. Not only is the heat of combustion entirely lost, but only a trifling percentage of the carbon content is recovered. Less than a pound and a half of carbon black is obtained from each thousand cubic feet of gas. The manufacture of carbon black from natural gas in populous regions is an industrial perversion of the worst sort. It arises from conditions of overproduction and competition; in such circumstances, and in view of the simplicity of the process and the small investment required, it is often more profitable to the producer of the gas to cull a little soot from this high-grade product and realize upon it immediately than to develop a real market for his commodity. During the war the manufacture of carbon black was summarily stopped in many localities, but all restrictions have since been removed.

Another serious difficulty in the way of efficient exploitation of natural gas is the all too frequent provincialism of public opinion in respect to this product. This situation is reflected in the attempts of states which produce natural gas to prevent its sale in adjacent states, even though the local output is in excess of local needs. Attempts have been numerous to hinder the normal interstate traffic in this commodity, not only by direct legislation forbidding export but indirectly by placing such restrictions on pressure that the high pressures necessary for long-distance transmission become illegal, as well as by imposing discriminatory taxation in favor of local consumption. S. S. Wyer, who has perhaps given more attention to the conservation of natural gas than any other engineer in the country, writes in this connection:

> The provincial habit of looking at natural gas from the dwarfed viewpoint of local use and immediate present is the primary cause of our acute natural gas service problems of to-day. The history of the industry has been one of unrestrained waste and profligate disregard for the public's interest, inevitably increasing demands, and obvious physical limitations of supply. This wanton waste has been emphasized by creating and then empha-

sizing provincial aspects rather than recognizing the true national and inter-state nature of the business. The selfish motive of trying to keep the natural resources of a state within the state boundaries, so as to make the consumers locate within the state boundaries in order to enable them to use the resource, has been the dominating feature. . . . If it would be just for any state to say that you can not use "our" natural gas unless you locate within our state boundaries, it would be just as fair for the Minnesota farmer to say you can not eat my wheat unless you live within the state boundaries of Minnesota, or for the Louisiana sugar planter to say you can not use my sugar unless you come and live within the state boundaries of Louisiana. The last two viewpoints are so ridiculous that they would not receive serious consideration; yet they represent precisely what has been specifically attempted in the distribution of natural gas.

Natural gas is the least appreciated, consequently the most abused of the mineral resources in popular use. The issues involved directly concern a tenth of our population, but their range of influence does not stop even here; they form, in addition, a prominent feature in the nation-wide problem of fuel supply which can be solved effectively only through coördinated attention to its component parts. Science and technology, working together, can take the initiative in simplifying this problem by pointing the way and devising means for the solution; but further than this these forces alone are powerless to go. The responsibility of initiative in carrying forward the actual process of solution rests with the public. Progress, therefore, depends upon a public opinion genuinely alive to the situation. This condition of affairs is most pronounced in industrial connections of the public service order, to which the activities comprising the natural gas industry belong; and the natural gas situation, bad enough from environment, is further aggravated by the peculiar characteristics inherent in the resource. The public must look to remedying the situation or within a very few years lose the service of a resource already seriously impaired.

Wyer sums up his views in reports to the Fuel Administration and the Smithsonian Institution, as follows:

> True conservation is not hoarding, but the wise use of natural resources, and it implies not merely the preserving in unimpaired efficiency, but also a wise and equitable exhaustion with a maximum efficiency and a minimum waste. The heart of the natural gas conservation problem is the conflict between the present and the future. The individual land owner is interested primarily only in immediate present personal returns. That is, he is thoughtless and indifferent with respect to the future. The public—at least the 2,000,000 domestic natural gas

consumers and the 10,000,000 people dependent on natural gas for their cooking, heating, and lighting purposes —are interested in conserving the supply and bringing about a slow, wise, and economic exhaustion, so as to insure continuity of service for the future. Conservation, therefore, demands intensive rather than extensive use, takes cognizance of equitable distribution, aims to bring about social justice, and means the greatest good to the greatest number—and that for the longest time.

In an address before the Natural Gas Conservation Conference held in Washington on January 15, 1920, Wyer said regarding the natural gas industry as a whole:

> The rate of decline of the industry's field resources has been so rapid, and the provision for taking care of that depletion has been so inadequate, that, based on personal investigation of over one-half of the natural gas industry in the United States, I am sure that at least three-fourths of the natural gas companies in the United States will be insolvent inside of three years if . . . the practice of selling natural gas at a figure so low as not to place any incentive on saving the gas, but actually putting a premium on waste, because the gas is cheaper than any efficient appliance that can be purchased or used to save it, is not corrected.

The elimination of waste in natural gas will require primarily the following measures: (a) Establishment of an adequate price for natural-gas service, capable of making the gas worth saving, and sufficient to discourage its use for industrial purposes where coal would suffice; (b) development of legalized "unity of action" in production so as to permit pooling of future field operations for the purpose of efficiency and economy; (c) general introduction of gas-measuring apparatus to check input and output of main lines and city distributing plants; (d) use of more efficient appliances by the domestic consumer.

But direct measures of conservation for natural gas are not all that is needed. The natural-gas problem is fundamentally an integral part of the gaseous-fuel problem, involving the manufacture of gas from coal; and hence constructive attention must be accorded the whole matter of gas, if adequate progress is to be made. Not only does natural gas to-day enmesh with manufactured gas in many localities where the artificial product has already been requisitioned as a supplement to an inadequate natural supply, but ultimately natural-gas service is due to be entirely superseded by gas made by man. It is important that public opinion be brought to realize the tremendous possibilities of advance open to the gasification of our solid fuels, and that a coördinated development of natural gas and manufactured gas under an enlightened public policy will strike to the heart of the whole domestic-fuel problem, giving the homes of the country a cheap and convenient fuel for years into the future, and making an inestimable contribution to the cleanliness and healthfulness of our cities.

CHAPTER VI

WATER-POWER, AN UNUSED ANNUITY

BEFORE the advent of electricity as a force under the control of man, energy was inseparable from a material expression. The methods of employing power grew up under the limitations of this dependence, as illustrated in the distributive use of coal. But now a command of the electrical principle makes it possible to deal with energy freed from substance. This not only concerns coal, by providing the means for extracting the energy at the point of production instead of at the many points of use, to the gain of efficiency and the saving of transportation; but it applies also to water-power, a resource hitherto fallen into disuse because of its inability to cope with coal, but reintroduced by electricity upon more advantageous terms, to the virtual gain of a new energy resource. Despite the fact that electricity has been in common and growing use in this country for many years, it has effected virtually no change in the basic conventions of coal distribution, and has led to the development of a small fraction merely of the available water-power.

As electricity has rehabilitated water-power, thus making available two energy resources where there was only one before, it is desirable to determine the resource status of water-power as compared point for point with coal power. The two are of necessity coming into competition, and unless water-power in its new habiliments can stand on a reasonably equal footing, the outcome of the competition is bound to be in favor of coal, as occurred before when steam-power drove hydraulic power to the wall. In which event water-power, despite its advantages for purposes of conservation, would have no special commercial significance for the present.

In respect to the size of the resource reinstated by electricity there can be no fault to find. Efforts to determine its magnitude have led to estimates placing the possibilities of hydroelectric development in the neighborhood of one hundred million to two hundred million horse-power, of which some fifty million is capable of use without special provisions for storage. Expressed in another manner, the water-power of the United

States, converted to electrical energy, is capable of turning every industrial wheel and illuminating every street and building in the entire country. And, the resource is country-wide in distribution. (See figure 24.) The apportionment amongst the various sections is by no means even, but the supply is more widely and equably spread than is the case with the coal-fields; and the regions distant from the sources of coal are all bountifully favored with water-power. Thus New England, the South Atlantic States, the Southwest, and the Pacific slope, together embracing over half of the potential water-power of the country, are all virtually without coal and bear testimony to this complementary distribution of power resources.

This balanced occurrence has considerable bearing upon the welfare of the nation, as treated at some length in Chapter X, under the caption "The Equalization of Industrial Opportunity."

The discrepancies in the various attempts to inventory the water-power resources of this country are due to several qualifying factors, notably that of storage. As the demand for power is commonly uniform the year round, the capacity of a given site for sustained effort is determined by the period of minimum flow. Accordingly, stor-

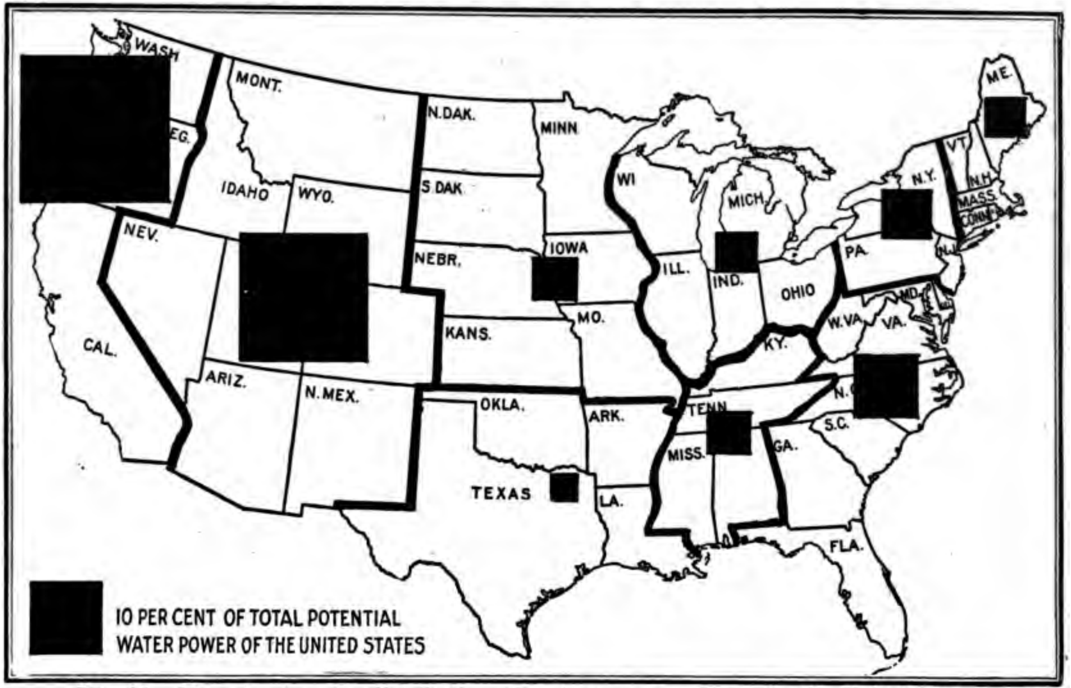


FIG. 24. Map showing the distribution of water-power resources in the United States.

TABLE SHOWING DISTRIBUTION OF WATER-POWER IN SECTIONS LACKING IN COAL

(Figures approximate and given in round numbers)

	Potential water-power (percentage of total in U. S.)	Unmined coal (percentage of total reserve)	Unmined oil (percentage of total reserve)
New England States...... (Maine, Vermont, New Hampshire, Massachusetts, Rhode Island, Connecticut)	3 per cent.	None.	None.
South Atlantic States..... (Delaware, Maryland, Virginia, South Carolina, Georgia, Florida)	6 per cent.	1 per cent. (virtually all in Va. and Md.)	None.
Southwestern States...... (Arizona, New Mexico, Oklahoma, Arkansas, Louisiana)	6 per cent.	4 per cent. (mostly in Okla. and Texas)	52 per cent.[a]
Pacific States............ (California, Oregon, Washington)	43 per cent.	2 per cent. (mostly in Washn.)	31 per cent.
All other States..........	42 per cent.	93 per cent.	17 per cent.

[a] Includes Kansas.

age provisions doubling the flow merely during such periods will double the year-round capacity. Steinmetz has calculated the total potential water-power of the country by superimposing a map of rainfall in the United States upon a map of elevations above sea-level, with the conclusion that the maximum energy that can be extracted from this source is 230,000,000 kilowatts. This amount is but slightly greater than the total energy which we now produce from coal, and approximates the total energy consumption of the country, including all forms of energy. The conclusion arrived at by this form of calculation is rather startling, as it "means that the hope that when coal alone begins to fail we may use the water powers of the country as the source of energy, is and must remain a dream, because if all the potential water powers of the country were now developed, and every raindrop used, it would not support our present energy demand. Thus hydraulic energy may and should supplement that of coal, but can never entirely replace it as a source of energy. This probably is the strongest argument for efforts to increase the efficiency of our methods of using coal."

Although the absolute extent of our water-power resource has been variously established on the basis of engineering data, with a limit set by theoretical calculations as noted above, the definitely determined working capacity of this source of energy is very great, representing the equivalent of hundreds of millions of tons of coal. But despite the advantages of magnitude and wide distribution enjoyed by water-power, this resource has not been able so far to enter into serious competition with coal. Only some 10 per cent. of the total expansion in power consumption in recent years has been in the direction of water-power. The present production of hydroelectricity in the United States represents roughly the equivalent of 55,000,000 tons of coal, whereas nearly 400,000,000 tons of coal go into the production of steam-power and carboelectric power.[1] The water-power developed is about 15 per cent. of that readily available; scarcely 7 per cent. of the total open to development under elaborate arrangements for storage. (See figure 25.) Estimates of this kind, however, are provisional only, for the amounts of the "readily available" and "total" are not accurately known nor definite. As a matter of fact, reliable information on the water-power resources of the United States is all too meager, considering the national importance of the field.

The favorite explanation for the laggard growth of water-power developments in the United States ascribes the whole trouble, either directly or inferentially, to the handicaps imposed upon private initiative by the inadequacies of Federal legislation. The facts do not bear out such conclusion further than to accredit this factor with contributive importance. Federal permits are necessary for the development of 75 to 80 per cent. of the potential water-power of the country, the balance being accessible without Federal permits. About 4 per cent. of the restricted portion and about 25 per cent. of the part outside Federal surveillance have been actually put to work. The discrepancy between the two is impressive, but even

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[1] The term carboelectricity is self-explanatory; it is used to cover electricity generated from the carbon fuels, such as coal. It stands in contrast to hydroelectricity generated from water-power.

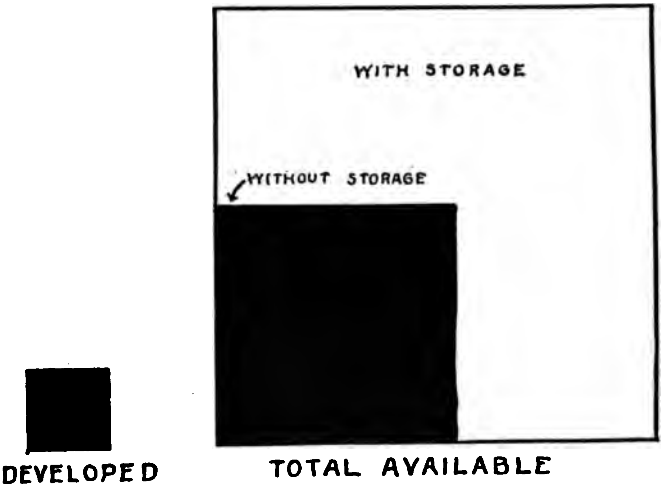

FIG. 25. Chart showing the developed water-power of the United States contrasted with the total resource.

granted that this is attributable wholly to Federal interference, which is not the case, it will be seen that the non-development of three-quarters of the potential water-power of the country remains to be accounted for on another basis. In other words, the quality of Federal legislation, even under sweeping concessions to its untoward effect, provides but a minor element in the complete explanation. Of course, the whole default may be attributed to the Government's *lack of action*, but the result of ill-advised legislation, while significant, has been exaggerated.

The specific obstructions to the unfoldment of water-power will be looked at later, but back of these instrumentalities is a fundamental economic setting which is essential to the view. The main features of this background are two in number. One is concerned with a relation between the power resources; the other with the force of convention in respect to power usage.

In the first place, coal and oil have been so bountiful in this country that only the cream of the deposits has been exploited; a project contemplating the development of a water-power site faces competition with such a situation. Our fuels have been mined on such an extravagantly uneconomical basis of opportunism that a superabundance of coal and oil has been maintained on the market. It may sound as if one were making light of the facts in speaking of an overproduction of coal and oil at a time when every one has been meeting on every hand a shortage of these basic materials. Yet it is well within conservative figures to assert, even without reference to water-power potentialities, that this country has long produced more than double the amount of coal and oil really needed under proper usage; and, of necessity, the surplus has had to be consumed in the form of waste. Overproduction leads to waste; waste leads to overproduction; and so the circle goes on unbroken. With no pressing commercial necessity for introducing economies in the use of coal and oil, there was still less of urgency to call the more basic economy of water-power into play.

In the face of such a situation, however, our richest and most favorably located water-power sites have undergone development. It is evident, then, that the cream of the water-power resource has demonstrated its capacity to compete with the cream of the fuel resources, and it is a fair assumption that the balance is reasonably even in this area of rich values. But most of the cream, aside from that withheld by Federal restrictions and assiduously sought after by special interests with a taste for such matters, has been skimmed from water-power, while it has not yet been exhausted from coal and oil; and the average of hydroelectric power, under present conditions, cannot compete against the residuum of cream now being assiduously removed from the other two. But the course of preferential skimming will tend to equal matters up, and a steady increase in the significance of the water-power resource is to be anticipated.

It is evident, of course, that considerable coal and oil are being sacrificed for the sake of giving water-power a better resource standing. This, in a national sense, is unfortunate; for the coal supply, while great, is not unlimited, and its needless use involves the loss of coal products, the true importance of which in a few years is bound to be recognized; while the petroleum reserve is already on the verge of exhaustion. The fuel resources are fixed in quantity and are in the nature of capital which does not draw interest; water-power, on the other hand, may be compared to an annuity, the annual increments of which lapse if not currently used. Hence, as a concession to convenience and in the flush of resource wealth, this country has run into the economic impropriety of drawing upon its energy capital while neglectful of its energy annuity.

In the second place, the use of fuel is the established convention for covering the needs for power. Where steam-power is wanted, fuel of course must be used. But even when electricity is required, fuel is usually the most convenient source. For purposes of generating electricity the primary power is ready at hand in the case of operations already established on a steam-power basis, while for the service of expanded or newly projected operations the simple expedient of enlarging or at most erecting a steam-power plant is all that is necessary. In either case the first cost is low, and the chief element in outlay is the expenditures under the heading of fuel purchases, which follow along steadily, but are distributed over the subsequent years of operation. The current proceeds from these operations are counted on to care for this train of expense; hence, from a pecuniary point of view on the part of a given industrial activity, there is no occasion for advance effort in capitalization under this head beyond the amount called for in connection with the subordinate item of cost for the erection and equipment of a steam-power plant. In the case of hydroelectric development, on the contrary, the conditions are reversed, and the whole weight of emphasis falls at the outset on the initial cost of power-site development. The running cost of hydroelectric power consists mainly in the single item of interest money on the capital represented in the initial outlay. An analogous condition would obtain on the side of coal-generated electricity if a given enterprise were called upon to provide an adequately equipped coal-mine in addition to the power-plant itself. In the one instance, as matters now stand, the coal-mines are already established in lavish numbers and do not enter into investment calculations; in the other, the power sites, with choice exceptions, still lie fallow and have yet to be developed if they are to be used. This is the situation facing any given industrial enterprise, however large, in respect to establishing its source of power. For the hydroelectric alternative to be chosen, it must present more than equal advantage. Indeed, it must be decidedly preferable, for projects in process of formation or expansion are likely to find their capitalizing ability pretty fully exercised without taking on the development of any special source of power, whether in the nature of a coal-mine or a water-power site. Therefore, in the process of natural selection exerted by business enterprise, water-power is usually set aside as presenting claims inferior to coal.

This holds true not merely for manufacturing projects, but for purely electric-power projects as well. No exception is found even in those common instances of municipal electric-power supply, where the bulk of the consumption is on the basis of pay the price or do without. What is the use, in these cases, of undertaking the tremendous extra effort connected with developing a special water-power source, even granted an ultimate saving in cost? A public-utilities commission would in all likelihood force a corresponding reduction in price, and all the effort would come to nothing really worth while, as these projects are in the nature of public-service corporations (a designation not altogether clearly understood, being sometimes construed as implying corporations serving the public instead of being served by the public). The public at large can be relied upon to pay any price conventionally established just so long as the actual cost of production is sufficiently high to prevent the rate from appearing extortionate; hence, no one gains by lowering the cost of production—except the public, which goes, therefore, to no account. A special price may even be quoted to industrial users to discourage the larger interests from generating their own electric power, as they have a choice in the matter which the public does not enjoy. Thus the river that flows through the town has the beauty of its course unsullied by commercialism. Instead, a trolley park, with merry-go-rounds, dancing pavilions, loop-the-loops, and the like, occupies the power site. With its art and enterprise catered to in this way, American municipal life in plentiful instances, not excepting that of the capital city itself, is disposed to rest content.

Thus, industrially and civically alike the electric-power situation is stagnant, caught in a backwater of convenience, with the course of progress blocked by the obstacle of initial cost. But it is not hydroelectricity alone which has its progress so obstructed. Its case is conspicuous because the resource itself is largely cut off from employment and advertises the inadequacies of the situation broadcast over the landscape. The shortcomings with reference to carboelectricity are not so obtrusive and therefore not so notorious; they are not heralded openly by actual disuse, but are cloaked instead under conventional misapplication. Commonly as much as a fourth of the coal-fired power employed in centers of population has its energy applied in the form of electricity.

Yet, with the rarest exceptions, this energy is transported to the centers of use in the form of coal and there the electricity is generated in steam-power plants. Electric-power usage has merely been appended to the established structure of steam-power practice, with the result that the employment of power has been greatly facilitated, to the further aggravation of the broad problem of transportation. So far the very force that has the capacity to correct the transportation evil has merely served to accentuate it. By virtue of electricity more power is consumed, more raw materials are required, more goods are produced, more coal is freighted.

The distributive generation of electric power was natural enough and the only practical procedure so long as the use of electricity was small. But that time has passed. Electricity is now a commodity in everyday use, with a large and steadily growing aggregate demand; to adhere to the original practice bespeaks obsolescence. Such escape as has been made from the confines of stagnation has been almost wholly in the direction of hydroelectricity. So, despite the great amount of talk and publicity that centers around the water-power issue, there is more evidence of basic progress on this score than may be found on the side of coal power. All that may be fairly said in dispraise of the progress of this country in respect to water-power is likewise true as regards coal. In fact, this country does not face a water-power problem as such; the issue is more broadly a power problem, of which water-power constitutes only one important segment.

Objection may arise at this point that a systematic generation of electricity in coal-fields is prevented by technological difficulties in the way of long-distance transmission of power to the points of use. It is true that there are many open problems in long-distance service of this kind, but these are by no means insuperable; granting them full weight and considering merely what has been already accomplished in connection with hydroelectric transmission, we find that transmission lines 100 miles in length are common, while those up to 250 miles in length are known and regarded as practical. If we accept say a 200-mile radius as a present standard, and consider the distribution of the coal-fields of the country in relation to the centers of population, we find that circles may be drawn around centers of coal production which will embrace a considerable area and much of the industrial territory of the country. On the basis of present technical attainments alone, with no allowance for improvements under way, a large share of the current power demand could be supplied directly over wires from the coal-fields.

Such a change in practice would operate to the relief of transportation and on this score contribute a country-wide advantage. But it would also create special industrial opportunities which would fall only within the reaches of the transmission systems. Hence, to plan a comprehensive development of the areas in proximity to coal-fields would be to emphasize and accentuate the advantages of environment which are already proving hurtful to the economic growth of the country as a whole.[1] The economic gain that would come to outlying sections through the general betterment of transportation would certainly be more than offset by the economic losses resulting from the increased disparity in power supply.

There is no occasion, however, to confine attention to coal-field developments without regard to the distribution of water-power resources, which, as already noted, bulk largest in the regions lacking in coal. Rather than single out the coal regions for favor, it would be preferable to take the opposite course, leaving the near-by sections to be served by freight-hauled coal and relieving the longer hauls by promoting the systematic development of outlying water-power sites, and thereby not only help transportation to better advantage but conserve the natural resources involved and diffuse industrial opportunity as well. But fortunately the two lines of action are not alternates. On the contrary, they enmesh in a singularly perfect manner and lead to a common end. In this light it is important to review more specifically the obstacles which have hindered water-power and all but excluded coal-power from assuming the complementary rôles to which they are admirably adapted by virtue of their natural dispositions.

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[1] See *The Equalization of Industrial Opportunity*, pp. 291-310.

Of the two, water-power may be looked at first, because it is the more conspicuous in its failure and in extenuation offers reasons complicated by a greater scope of variety. For the most part these qualifications have already been examined; and, besides, to a great degree, they are either self-explanatory or at least have been given sufficient publicity of discussion to be more or less common property. Accordingly, in the interest of brevity, they may be listed with a few comments only, rather than gone into at length.

1. *Adverse legislation.* Here the situation has

been clouded by various issues of Federal, state, and individual rights, covering not only the immediate subject of power, but sundry other uses, such as steam-navigation, likely to be interfered with. In view of these complications, legislation has characteristically been framed with an eye toward legalistic ends rather than in the direction of a genuinely constructive economic outcome.

2. *Public sentiment.* There is a general feeling—natural enough in the strength of its hold—that in the beauty of the country's rivers, with their rapids and waterfalls, adheres a certain nobility of function whose grandeur is the common birthright of all. The surrender of this heritage to the interests of commercialized service is a line of conduct not likely to meet with public approval. Whatever of actual substance in the way of purpose is to be recognized in the fabric of legalism, as noted under the previous caption, has been contributed largely in response to this attitude of public sentiment. The attitude has unquestionable justification and must be reckoned with. Those on the one side who would have it ignored are as far wrong in the solution of the water-power issue as those who would give it unqualified heed. Yet the principle is universally recognized that the interests of beauty must give place

to pressing needs of utility. This consideration alone would not give rise to disfavor in regard to water-power development. The source of disapprobation lies in the lack of vivid appreciation as to the matter of need, coupled with the attendant imputation of surrender to vested interests. Accordingly, the water-power situation cannot be satisfactorily cleared up until the need for the systematic development of this resource is firmly established; until freight congestions, fireless homes, food-stuff costs, and other intimately personal issues are seen to be genuinely involved; until the opportunity for the restrictive furtherance of special interests, financial or sectional, has been eliminated. Until these conditions have been met, attempts to promote the development of our water-power resources are bound to result in ineffectual compromises.

3. *Cost.* A hydroelectric station, once established, is largely self-contained and automatic in operation. There are no periodic items of cost for fuel, for freightage, haulage, handling, and the like, such as associate themselves with the operation of a steam-power plant. So, apart from such incidentals as administration, insurance, taxes, and depreciation, which together bulk small, virtually the whole burden of gross operating ex-

pense is that assumed at the outset in the guise of initial cost and perpetuated in the form of interest money.[1]

Expense	Steam station (per cent. of total gross operating expenses)	Hydroelectric station (per cent. of total gross operating expenses)
Administration	4.0	4.0
Ordinary operating expenses (except coal)	10.6	4.8
Coal	48.9	....
Taxes and Insurance	6.7	2.8
Depreciation	10.8	11.0
Bond interest	19.0	77.4
Total	100.0	100.0

Thus the cost of money, displaying itself in bond interest, is the determining factor in the cost of hydroelectric power precisely as the price of fuel, with its accompaniment of expense, determines the cost of steam-power. The cost of money in this country, on a strictly commercial basis, is high. The prevailing rate of interest demanded of water-power developments before the war was about 7 or 8 per cent., which, with discounts taken into consideration, normally meant a demand amounting to 9 or 10 per cent. on the working proposition. Estimate after estimate the country over has gone to show that only the water-power site especially favored by natural advantage is susceptible to development under these conditions in competition with the prevailing cost of steam-power. These favored examples also frequently provide a bone of contention over which conflicting interests raise a great to do, tending to create the impression that the water-power resources of the country constitute a tremendous asset whose possibilities are being arbitrarily withheld from their normal course of unfoldment. Nothing could be much farther from the truth. With the exception of the few conspicuous instances that serve as a stimulus in keeping the question alive, no particular significance attaches to the country's undeveloped water-power under existing conditions of finance, or will, until either these conditions have been lived down or steps have been taken to better them. The former represents a tendency which left to itself is not likely to yield anything of consequence for years to come. Nor is there any room for hope in technological advance. The issue of cost is a matter which, like the legal and sentimental obstacles just outlined, must be overcome, and the only way in sight lies through arrangements which will impart a degree of stability to water-power securities such that they will receive the benefit of a reduced rate of interest. This phase of the subject will receive further attention in Chapter IX.

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[1] A unit analysis of the gross operating expenses of a typical steam-electric and hydroelectric station of the same capacity (20,000 horse-power; annual load factor, 50 per cent.; coal, at $3.25 per ton delivered) is given as follows by Gano Dunn, "The Water-power Situation Including Its Financial Aspects," Proc. Amer. Inst. Electr. Eng., May, 1916, p. 585.

Thus, the influences holding back water-power development are of a threefold order. These do not operate separately but in conjunction with one another. Water-power development stands in need of special consideration; instead, it meets with special opposition. There is none to work in its behalf except those with special objects in view, and the recognition of this quality in their efforts has gone to establish opposition. The contention in this wise has grown to be organized on both sides, with each alike oblivious to the real community of interests involved and legislative action caught fast in an entanglement of compromise. In all three respects the situation is in a deadlock and the likeliest chance of a break toward progress lies in the entry of a new standard in the field, a standard under which the rights and best interests of all concerned can have the assurance of fitting recognition.

CHAPTER VII

SMOKELESS FUEL AND CIVIC PROGRESS

THE United States in 1920 produced in round numbers 645,000,000 tons of coal. About one seventh of this, or 89,000,000 tons, was anthracite, while the rest was bituminous coal of various grades. The anthracite came from a small area of less than five hundred square miles in Pennsylvania; the bituminous supply, from thirty states, with Pennsylvania, West Virginia, Illinois, and Ohio contributing about three fourths of the total.

Anthracite is hard coal, of uniformly high heating value, and burns without smoke; it is relatively costly to mine and prepare; it is regarded as the ideal fuel for the American home. Bituminous coal is soft coal, of slightly greater thermal value in the raw state as compared with anthracite, and burns with the production of black smoke; it is cheaper to mine and to prepare than anthracite; it constitutes the dominant fuel dependency of American industry and commerce, and is used in American homes that cannot afford anthracite. Vast quantities of coal lower in grade than bituminous, such as lignite and peat, occur in many parts of the United States, but these as yet are virtually untouched.

Coal as now used fulfils three distinct and unrelated functions. It furnishes industrial power, material for the manufacture of coal products, and domestic heat. About two thirds of the coal consumed in the United States goes into the production of power which is divided almost equally between the industries and the transportation systems; about one sixth is used as a raw material for making substances employed industrially, such as metallurgical coke, upon which the iron industry depends, and gas, nitrogen compounds, benzol, tar, and coal-tar products. One sixth approximately is employed for heating homes and other buildings. It will be observed, then, that the combined industrial requirements outweigh the needs of the home five to one. (See figure 26.)

This threefold function of coal involves the element of competition, which is latent in normal times, but becomes effective in periods of stress. War conditions in America developed in acute form the inevitable consequence of this competitive tendency,—a shortage of fuel for domestic heating. Industrial users of coal are strong and preponderant; they can meet a growing cost by passing it on to the consuming public in the form of higher prices; and in cases of shortage they are normally given precedence in distribution. Domestic users of coal, on the contrary, are scattered and weak; in general they must accept what is left after the wants of industry are satisfied. The home, therefore, is forced to pay a price developed by the industrial demand, or else, if the price be artificially fixed, suffer more than its relative share of the shortage which the expanded demands of industry create. This condition was not peculiar to the war situation, though never before, of course, so gravely manifest; it is inherent in our present system of fuel utilization, which if unchanged may be expected to display a repetition during every future period of industrial quicken-

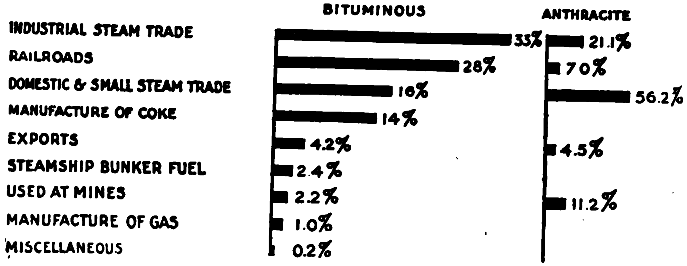

FIG. 26. The utilization of coal in the United States.

ing. Moreover, the growth of industrialism, by increasing the industrial consumption in excess of the domestic, will serve to make the danger progressively more serious.

The competitive tendency that now obtains between the three main uses of coal is not justifiable on the basis of the character of coal itself. On the contrary, these functions, at present antagonistic, are fundamentally complementary, and they can be made so in practice to their common advantage, in respect to yielding cheaper products to all interests as well as to imparting a stability and elasticity to the supply that will better enable it to weather periods of stress. In the ideal utilization of coal, the domestic and commodity uses will be completely complementary, while the power use will supplement the other two. Each will benefit from the others, and no one can be adequately developed without the participation of the others. The means whereby this advantageous coöperation may be effected are feasible and within the reach of an immediate start toward realization.

The point of logical attack upon the coal problem, then, centers in the home, for here lies the greatest weakness in the present system of coal utilization. It is in the home that conditions are the most discomforting in times of stress, that trouble, whether it be of high price or actual shortage, has the least chance of remedy by industrial enterprise. The problem, too, finds its closest contact with the individual in the affairs of everyday life; and its complexities may be reduced to their simplest expression in terms of this point of view. But it should be clear that although the line of advance may start with changes that benefit the individual user of coal, the course of progress brings no less advantage to the field of industry. The whole matter, however, concerns the individual directly and foremost; he will be the gainer or loser according to whether or not he sees fit to interest himself in the means for effecting the progress not merely needed but absolutly essential to the well-being of the immediate future.

Approaching the coal problem from the point of view of the domestic user, we find that the homes of the country are insistent upon anthracite, in so far as its use is not precluded by expense or excessive distance from the area of production in Pennsylvania. Thus the entire northeastern part of the country is entirely, and contiguous territory as far west as St. Paul and as far south as Atlanta, is partly, dependent upon what is popularly termed hard coal. As is well known, this is due to the twofold fact that anthracite is clean, both in handling and in its smokeless combustion, and its heating effect is uniform and high. It is needless to add that the dependency developed because a coal resource of this type was present in a populous and accessible part of the country.

But anthracite is a luxury. It combines refinements of quality with limitations of supply,—the characteristics of every luxury. Its cost of production is approximately twice that of bituminous coal; it emanates from one region only, a district of heavy freight; it has no capability of yielding by-products to modify its cost; besides, a big fraction of the available supply is already exhausted. Its domestic use may be continued as a luxury, but anthracite must be dismissed as not equal or adapted to the task of supplying the American home.

The home, therefore, independently of its wishes in the matter, must turn to bituminous coal for its fuel dependency. There is no alternative. Already this has happened to a partial extent; war conditions accelerated the change; the future demands it more completely. The advantages of bituminous coal are well known,—its relative cheapness, its wide distribution, its ample reserves, the possibility of improved utilization. But there is one grave objection to the use of bituminous coal,—its dirtiness. This is a valid objection. Burned in the raw condition, it gives off dense black smoke which dirties the home, pollutes the atmosphere, and becomes the implacable enemy of civic betterment as well as a menace to the health of the city dweller. Such a result cannot be countenanced. It so happens, however, that smoke represents the most concentrated value in bituminous coal. If we can extract this value and use it toward reducing the cost of fuel, at the same time making a smokeless product for heating use, the sole objection will be turned into an advantage, and the domestic fuel problem will be solved.

In 1915, before the price of coal was enhanced by war conditions, the average value of bituminous coal at the mine was $1.13 a ton. By way of contrast, we may tabulate the latent values contained in an average ton of raw coal, giving the figures in round numbers and basing the calculations on prices prevailing in 1915.

Obviously, there should be a way for the home to get its fuel more cheaply than it has, when a dollar's worth of coal at the mine contains about

Balance sheet showing contrast between value of 1 ton of bituminous coal at mine and value of products which it contains, based on conditions prevailing in 1915.

COAL	Value at mine, 1915	PRODUCTS	Value at point of production, 1915
1 ton (2,000 pounds) bituminous coal contains	$1.13	1,500 lbs. smokeless fuel	[a] $5.00
		10,000 cu. ft. gas, at 90 cents per 1,000	[b] 9.00
		22 lbs. ammonium sulphate, at 2.8 cents	.61
		2½ gals. benzol, at 30 cts.	[c] .75
		9 gals. tar, at 2.6 cts.	23
Total	[d] 1.13	....	15.59

[a] Figure based upon approximate selling price of anthracite.

[b] Figure based upon average price of city gas.

[c] These figures would be much higher if an adequate coal-products industry were in existence.

[d] This figure shows clearly that lowering the cost of production cannot be expected to lower the price of coal. Even if the cost of production were eliminated, the price of coal would merely be a dollar less.

fourteen dollars' worth of commodities useful to society.

One answer to the question as to how these values may be won from coal lies in the development of artificial anthracite. The accomplishment depends merely upon the establishment of a process which will isolate the solid-fuel portion of bituminous coal in the form of a substance equivalent to anthracite, and produce from the remainder a number of products whose value could be made to more than carry the expense of the operation. Nature has pointed the way with natural anthracite, which was originally bituminous coal, but has subsequently, under the stress of geological evolution, lost its volatile portions, forced out by the action of pressure and heat. It is merely a matter of accomplishing a similar result by artificial means, but with the important advantage that while nature dissipated the volatile constituents and produced only one end product, man could catch these values and turn them to his advantage. There are no insuperable difficulties in the way of such an accomplishment. Several processes capable of this attainment are already in course of commercial development, although comparatively little organized research has been directed to the problem. An intensive attack, such as the importance of the matter deserves, would unquestionably yield an entirely satisfactory procedure. The problem, in reality, is rather one of economics than of technology. When the need for artificial anthracite is generally appreciated, a suitable process for its manufacture will be forthcoming.

Granted the necessity for a smokeless fuel other than anthracite and recognizing that it is chemically feasible to make such a product from bituminous coal, we may examine the existing economic practice that bears on this matter, with a view to ascertaining at what place, if any, a process as outlined above may be introduced and placed on a working commercial basis.

We naturally turn first to the coke industry, for here the greatest progress in coal utilization has been attained; and, besides, coke has already been used to a limited extent for domestic heating. The coke industry consumes nearly one sixth of our bituminous coal, and has as its immediate purpose the production of coke, a substance required by the iron industry, which absorbs most of the output.

Coke is made by heating certain classes of bituminous coal to high temperatures, with the production of a hard, porous residue, composed essentially of carbon. Two methods of manufacture are in general commercial use. One employs beehive ovens, so called from the shape of early types; the other makes use of retort ovens, which are usually long and narrow and assembled in batteries. The latter are appropriately termed by-product ovens, because they recover the commodity values contained in the coal.

The beehive oven delivers a product well suited to metallurgical use, but the process is objectionable because of the waste involved. It not only fails to yield the maximum of coke, but it effects no recovery of other valuable constituents. The products lost represent a measurable waste in terms of dollars, but they carry greater significance as being the raw materials upon which could be built the manufacture of fertilizers, dyes, drugs, and explosives.

The by-product oven receives raw bituminous coal and subjects it to destructive distillation. This process consumes none of the coal, but breaks it up into five components,—coke, gas, ammonia, benzol, and tar,—of which coke is the main product, while the other four constitute by-products. About half of the gas produced is used to supply the heat essential to the operation; the by-products are partly or wholly recovered according to the details of the practice. Where the by-products are wholly recovered, no part of the coal is wasted. In round numbers, 1 ton of bituminous coal yields 1440 pounds of coke, 10,000 cubic feet of gas, 22 pounds of ammonium sulphate, 2½ gallons of crude benzol, and 9 gallons of tar. Half of the gas is available for use as fuel or in lighting; the ammonium sulphate is a valuable fertilizer; benzol is an excellent motor fuel, a substitute for gasoline; tar is a waterproofing material used for making roofing and for dressing roads.

These four first-products have an unlimited field of usefulness as such. In addition, three of them represent raw materials upon which important fields of present industry are dependent and, if bountifully supplied, new industrial activities of far-reaching consequences can be reared. The ammonia, recovered as such instead of in the form of ammonium sulphate, forms the basis of modern refrigeration and is used for making explosives and chemicals. Benzol is a mixture of substances, including the deadly toluol, which can be made to yield explosives, dyes, drugs, medicines, solvents, photographic developers, and other chemicals. Tar, likewise, yields a ten per cent. fraction which may be turned into explosives, disinfectants, dyes, drugs, and other products. Benzol and tar, in short, are the basis of the coal-tar industry, inadequately developed as yet in America,—an industry which Germany has intensively cultivated to an advantage now well known.

The by-product oven is complicated and costly to install and to operate. Like the beehive oven, its prime purpose is to deliver coke, but it can compete with the beehive only when the by-products can be disposed of with sufficient advantage to cover the greater expense of by-product practice and contribute a margin of incentive besides. The development of by-product coking in the United States has been slow, considering the social and national importance of the possibilities inherent in this activity. At the beginning of 1921, the beehive oven still turned out about half of the coke produced, although war conditions and war demands gave a strong impetus to by-product developments.

The reasons for the lagging growth of by-product coking in America are clear and specific. There has not been a sufficient demand for all five of the products, due to inadequate industrial utilization of gas and the virtual lack of a coal-tar industry. Our economic adjustment gave a stable demand for only two of the products, coke and ammonia. The gas had a varying value from a product representing the chief source of revenue in some instances down to one giving returns too small to justify its storage. In 1915, for example, the average price of city gas was ninety-one cents per thousand cubic feet, while the average price of gas from by-product coke ovens was ten cents.

The benzol, a few years back, was not even recovered, there being no demand for it. The tar, like the gas, had a considerable though low range of value, but until a few years ago its extraction was scarcely profitable.

The consequences of inadequate coal-products development in the United States have been serious, in some respects critical. Here falls entire responsibility for war-time shortages in explosives of certain types, as well as in dyestuffs, and a variety of drugs and chemicals; partial responsibility for the high cost and inadequate supply of nitrogen compounds; and even a little of the blame for the transportation congestion of 1917–18, which industrial coal-gas utilization could have alleviated in some measure. These considerations are apart from wasted materials and wasted opportunities. The coal-products situation, indeed, represents one of the most complex, subtle, and important problems in the whole field of industry to-day; and this is true not only in respect to present conditions, but also as regards the trend of future industrial growth to a degree difficult of full appreciation. The failure of Great Britain to sense its importance before the outbreak of the European war came desperately near causing her defeat during the first few months of hostilities through a lack of toluol; the situation was saved only by the chance that the British gas industry was developed with by-product recovery and by straining met the emergency. A similar omission on the part of the United States was responsible for some of our embarassments. A failure to remedy the situation will place this country at an unfortunate disadvantage in the future. It seems remarkable that a single, partly developed unit of industry can have such a vital and far-reaching bearing on the well-being of the entire nation, but such is unequivocally true of coal products. That fact cannot be expressed too plainly or in terms too strong.

To build a proper coal-products industry, even within the limits set by the coke needs of the iron industry, will require the establishment of a steady demand for the four by-products, gas, ammonia, benzol, tar, which will give them a commercial value in keeping with their real worth. This, in turn, will depend upon an enlarged utilization of gas for fuel purposes, and the growth of a substantial coal-tar industry which to the certain values of the primary products will add indefinite constructive possibilities of increased values in a field already advanced to the point where warfare, textiles, and chemical manufacture are utterly dependent upon it. The whole accomplishment waits upon a constructive economic policy which recognizes in true perspective the pivotal importance of coal products.

The significance of the coal-products field and the need for its adequate expansion has been dwelt upon at length, because the matter concerns not merely the portion of bituminous coal made into coke, but bears with peculiar meaning upon the utilization of the much larger portion consumed as fuel.

Having examined the coke industry and observed its main purpose, the production of metallurgical coke, and the incidental recovery of by-products on the part of about half of the activity, we may ask if this industry cannot extend its scope so as to produce a surplus of coke which may be applied to fuel use. The answer is in the negative. Coke, being designed for another purpose, is not a satisfactory fuel. While smokeless in combustion, its cellular structure gives it an intensity of combustion and susceptibility to chill that renders its control troublesome. Even a radical change in furnace design cannot be expected to overcome this difficulty. Moreover, the coke industry is centralized, subject to marked fluctuations according to the demand for iron, and has not yet succeeded in modernizing more than half of its practice. Besides, its by-product manufacture is complicated and costly. Metallurgical coke, then, must be dismissed as an impracticable general-service fuel. The by-product coking practice, however, illustrates the principle of full coal-value utilization and therefore points the way toward progress in respect to fuel coal. Modified by-product plants, simpler than by-product coke ovens, producing a non-cellular carbonized residue and located near the points of utilization, represent the lesson to be drawn from the coke industry.

We may turn next to the gas industry to ascertain if this activity is capable of adaptation so as to contribute an adequate smokeless fuel for domestic and power consumption. This industry consists of a great number of separate plants, distributed, one or more each, among the cities of the country. In the aggregate these plants consume about one per cent. of the annual coal production of the country. Their prime purpose is to manufacture gas, and this they do without adequate regard to the complete recovery of by-products, although many plants effect a partial recovery of ammonia and tar, and some gas-house coke is put upon the market. Apart from the oil-gas plants on the Pacific coast, in which petroleum is used because of its relative cheapness in that region, the artificial gas industry of the country employs coal as its principal raw material.

Three types of gas made from coal are in general use,—coal-gas, carbureted water-gas, and mixed gas. Coal-gas is distilled from bituminous coal by heating the latter in retorts. Carbureted water-gas is produced as a result of the action of steam upon coke or anthracite, the non-illuminating water-gas thus produced being then "carbureted," or enriched, by the addition of a gas of high thermal and illuminating power, made from oil. Mixed gas is a mixture of coal-gas and carbureted water-gas and is supplied in many cities in the United States, the coke from the coal-gas production furnishing the basis of the water-gas manufacture.

The gas companies are public utilities. They manufacture a necessity which does not lend itself to competition. They are private enterprises under public control, which is largely directed, however, to price restrictions, and is not constructive in the way of compelling advances in technical procedure. With some exceptions, the average municipal gas-plant is a small and antiquated organization, both in practice and vision, far behind present possibilities of manufacture and application. In some cities in the United States the gas companies are in the nature of large public-service corporations, but nowhere is there full by-product recovery and the price of city gas is uniformly high.

Although the municipal gas-plant now meets rather inadequately only a small share of the fuel needs of the community which it serves, it represents an established activity which can be converted into an organization that will supply all the fuel, whether gaseous or solid, that the community requires. The transformation may retain the gas mains and much of the other equipment of the present type of plant, but in the place of the present procedure with relative neglect of by-product recovery will be substituted a by-product system of coal distillation, producing artificial anthracite, gas, ammonia, benzol, and tar. This will mean in each city a centralized purchase and consumption of raw coal, and a centralized distribution of products. The output will be limited at first, at least, by the demand for solid fuel. A production of ample solid fuel will give an excess of gas over that now produced, which will call for an expansion in the use of gas, both in the home and in industry. Such expansion will come as a result of cheaper gas, incidental to the proposed plan of production, together with improvements in methods of utilization; and this very expansion will cut down the use of solid fuel and thereby hasten the adjustment. The three remaining first-products, ammonia, benzol, and tar, as already pointed out, have an unlimited field of usefulness as such, even within the municipality; and by shipment will contribute a supply of raw material to the needs of the coal-products industry, thus stimulating this important field of endeavor to advance beyond the limits now imposed upon it by the coke industry.

It is not beyond the bounds of reason to foresee a condition whereby a householder, in the place of his ton of anthracite which he now welcomes for $11.00 will receive a ton of smokeless coal without slate, a month's supply of cooking gas, forty miles of motor fuel, enough fertilizer to start a small garden, and tar sufficient to allay the dust in front of his house—all for far less money than he now pays for inferior coal. This may appear a fanciful picture, but coal has precisely this possibility within itself.

The objection may be advanced that artificial anthracite has not been perfected and placed on a commercial basis, and until such time the utilization as outlined above must wait. It is indeed true that such a process is not firmly established in every detail and ready to be fitted into the present gas industry, but a similar condition has been a stage in the development of virtually every technological process and the recognition of the demand has created the means for its accomplishment. But even granting the objection as valid, we find that the production of artificial anthracite is only one of two solutions to the problem of developing an adequate smokeless fuel from bituminous coal. The prime idea is to separate the heat- or energy-producing portion of the coal from the constituents valuable as commodities, and dispose of the two groups to their mutual advantage. Hence, if we convert the energy component entirely into gas and recover the by-products, we may accomplish our purpose without calling into service a single procedure which is not already in successful practice in other fields of industry. The municipal gas-plant affords, in the second instance also, the logical point of attachment for the development. Only, in this event, in the place of artificial anthracite and gas, plus ammonia, benzol, and tar, the output would be gas entirely, with a similar production of ammonia, benzol, and tar.

The twofold possibility of advance in coal utilization brings up the relative advantage of smokeless fuel in solid versus gaseous form. For domestic purposes, solid fuel, such as artificial anthracite, requires no change in present types of furnaces and grates; is applicable to suburban and outlying districts not served, or servable, by pipes; and will always be in demand for open fires. Gaseous fuel, on the other hand, eliminates the factors of individual storage and haulage, reduces dirt, and through the automatic temperature control of gas-fired furnaces nullifies the conspicuous losses growing out of ignorance and carelessness in connection with present methods of hand firing. Gaseous fuel in the form of natural gas is already serving about ten per cent. of our population, and artificial gas must be developed to replace the waning natural-gas supply, if the extensive transmission and utilization equipment in the natural gas regions is not ultimately to be scrapped. For industrial purposes, gas offers conspicuous advantages, as evidenced by the varied industrial uses of natural gas in all localities where abundance of supply creates a low price.

In general, gaseous fuel is bound to increase in importance as compared with solid fuel, especially in the industries. While solid fuel lends itself to conversion into power only through the agency of the steam-engine, gas may be used in the internal-combustion engine; while for purposes of producing heat, gas presents an ease of control and a mobility of application that place it beyond comparison. Moreover, and most important of all, solid fuel has already reached a far fuller measure of development than has gas, whose utilization is still in a relatively undeveloped state. Improvements in the internal-combustion engine, the gas turbine, the utilization of gas under pressure, and the application of the so-called surface method of combustion offer lines of advance that will add a growing weight of superiority to the use of gas.

For domestic purposes, however, the advantages of solid and gaseous fuel are somewhat complementary, rather than opposing, so that advances toward perfecting the two types of fuel may well be simultaneous. The successful operation of an artificial anthracite plant will demand increased utilization of gas, involving the employment of the latest advances in its application; while the operation of an enlarged municipal gas-plant, with adequate by-product recovery, however effective in the way of economical gas supply, cannot be expected to replace fully, at least for some time, the need for a smokeless solid fuel. In either event, therefore, the tendency will lead toward an increasing rôle for fuel gas, a trend in line with the inevitable necessity for a more mobile and more efficient source of heat and power than is afforded by solid carbon.

The by-product utilization of coal, whatever the details of the process, may be extended, therefore, to meet an appreciable portion of the requirements of industry; indeed, its success even requires coördination with the fuel requirements of industrial activities. As already pointed out, development of artificial anthracite will give an excess of gas over present domestic wants which must be consumed, in part, for industrial purposes now dependent upon raw coal. Artificial anthracite would also be suitable for steam raising and therefore offer to industry the same advantages that it holds for the home, including the possibility, if fully used, of making our cities and railways completely smokeless. The adequate development of artificial anthracite, in coördination with a large coal-products industry, may be expected to create a competitor for raw coal that would gradually put it out of use in cities; for there is no insuperable reason why the fuel portion of coal should not be widely available at less cost than raw coal. The alternate plan of complete gasification of coal, with by-product recovery, as carried out in municipal plants, would of course offer abundant gas for industrial use in manufacturing centers; while at the mine, a similar procedure could be made to supply gas for distribution as such or convertible at once into electrical energy, susceptible of effective transmission over a radius of two hundred miles. Here the process ties up effectively with the national need for a balanced development of coal power and water-power, which will come about through the establishment of an extensive system of electrical transmission lines linking hydraulic power sites with power-stations in the centers of coal production, with coordinate development of the pipe-line transmission of gas. (See Chapter VI.)

The lack of progress in domestic fuel is influenced by habit and by the relatively abundant supply of anthracite heretofore available, but more fundamentally advance has been blocked by the virtual failure of public utilities in American municiple life. Had the public utility function been soundly developed in the United States, the fuel needs of each community would now be served by public-service corporations, at a saving to the community over the total cost of its fuel under present conditions and at a great gain to the community in cleanliness and health.

As the default is laid at the doors of public utilities, it is desirable to examine more specifically wherein this type of activity has failed; for it is obvious that if domestic fuel has not adequately developed because of a flaw in public utilities administration, it cannot be expected to develop adequately until this defect has been set aright. A public utility may be defined as a necessity in general use which does not lend itself to competition. This conception has been accepted for certain community essentials like water supply, gas supply, traction service, and the like. It is commonly recognized that the activities falling under such heads cannot be entrusted to the unrestricted competition of business enterprise.

But this recognition has been a matter of growth, not a sudden appreciation of the case. Looking merely at the main steps in the evolution of the public utility conception, we see that the distinctiveness of the field first met formal recognition upon the insertion of certain clauses into municipal franchises, imposing in advance the restrictions deemed necessary in return for the privileges extended. This course of action clearly established a field of operations that differed from the setting accorded industrial activities in general; public participation in industrial affairs thus had its inception. But, inside the restrictions agreed upon in advance, the operating company had the utmost freedom in regard to procedure, profits, and the like; under these conditions public-service organization still had incentive for advancing its practice and otherwise increasing its efficiency. This method of administration, however, while lucrative to private enterprise, proved a failure from a public-service point of view, due, in the main, to the corruptibility of municipal authorities. This régime covers a dark page in American municipal government.

Following the failure of franchise control of public utilities, another step in the direction of furthered public oversight was added in the form of public utilities commissions; this method of control has come extensively into vogue and its sphere of influence is spreading. The public utilities commission carries public oversight from its initiation in the franchise over into the actual operations of the activity concerned. This method of administration, for which American municipalities have held high hopes, has likewise failed. It has succeeded in removing the incentive for progress, which was still present under the franchise régime, without supplying any activating influence in its stead. It insures in favor of the public for the full gain of any increased efficiency that may come into play, but in so doing it removes the industrial motive that makes for increased efficiency. Protecting the public from the appearance of gross extortion, at the same time it prevents the public from gaining the advantages of technological advance. It puts a premium on stagnation; it defeats the purpose for which it was created. In the course of American industrial evolution, just in proportion as successive activities have come under our present type of public-utility control, to the same extent have efficiency and progressiveness fallen into abeyance. This is illustrated on the one hand by the gas-works—one of the earliest public utilities to come under the present type of control and hence notorious for its inadequate practice—and on the other by the telephone service, scarcely yet affected by public oversight and in consequence still efficient. Adequacy in industrial affairs seems to be in inverse ratio to the degree to which public oversight of the political type has been extended over them.

The successful development and operation of central municipal fuel plants, which will provide the fuel needs of the community in an efficient manner, will depend in large part upon public initiative and stimulus. Adequate progress can scarcely be realized until public-utility administration is conducted along constructive, rather than static lines, and this cannot happen unless a type of public management superior to anything this country has developed in the past can be put forth. The increasing price of domestic fuel and the growing murkiness of cities, however, may be expected to turn more and more attention to the fuel problem, and as soon as it becomes widely appreciated that the shortcomings in the situation are due to the lack of a proper plan for gaining progress, rather than to faults inherent in coal itself, a solution will be forthcoming.

In short, the trouble with the domestic-fuel situation is not any lack in supply or in the technical means for providing a cheap, efficient, and cleanly fuel service; but an artificial environment established by custom and law which renders wasteful methods profitable and which tends to make methods that are economical from a national point of view unprofitable and extra hazardous.

This chapter does not presume to set forth in final form the prescription whereby the domestic-fuel problem may be solved; the procedure remains to be worked out in detail. Its purpose, however, has been to present a line of attack, drawn up on the basis of the character and extent of the resource, which may be followed to specific advantage. There are no serious technical obstacles in the way; the chief requisite for progress is a popular appreciation of the fact that coal contains greater values than society is getting from it. From this realization will spring a public demand that scientific and technical knowledge be used, not merely in making improvements in the details of present practice, but in revising that practice itself and shaping a policy of administration more in keeping with what is known to be the potentiality of coal. "Mankind," writes John Dewey, "so far has been ruled by things and by words, not by thought. . . . If ever we are to be governed by intelligence, not by things and words, science must have something to say about *what* we do and not merely *how* we may do it more easily and economically."

CHAPTER VIII

POWER AND INDUSTRIAL PROGRESS

THE United States places special emphasis upon the use of power. With national prosperity, abundance of resource wealth, and dearth of labor, American industrial enterprise has naturally turned to the creation of labor-saving machinery and provided for its efficient employment through the medium of standardized volume production. Thus the fabric of American industrialism is colored by the machine process and the large-scale operation to a degree not equaled elsewhere in the world; while mechanical appliances and mechanical service have reached out into domestic life in a pervasive manner. These conditions have created and sustained a scale of living without parallel amongst other nations. To support this situation, this country consumes nearly half of the world's output of coal and over half of the total production of petroleum, not to mention the employment of water-power, natural gas, and minor sources of power in large quantities.

This unprecedented consumption of power places a heavy strain upon transportation, both directly by virtue of the bulk of the power materials to be moved (coal alone represents over a third of the country's freight) and indirectly through the haulage of materials and products involved in the industrial processes. The responsibility thus falling upon transportation is added to in further degree by the size of the country. The presence of a population scattered over a vast area, with a standard of consumption cut to the measure of a concentrated industrialism, attaches the element of distance to the factor of bulk and imposes an accentuated dependence upon adequate carriage. Thus in two respects the transportation problem in the United States is unique.

But national dependence upon transportation, so highly developed by virtue of the advanced state of industrialism and the areal extent of consumptive demand, is increasing. The rapidly enlarging use of power and the growing burden of commodity haulage arising in consequence, to say nothing of the claims of foreign trade, give no prospect of letting up. Every time an individual adopts a mechanical appliance or purchases an article hitherto made at home or gone without, thousands of others are doing the same thing. Society will not turn back now; presently it cannot turn back any more than it can to-day weave its own garments by hand. The convenience of to-day is the necessity of to-morrow. If we project the present trend of requirements even ten or fifteen years into the future, we begin to gain a true perspective of the imposing weight of the transportation problem that industrialism faces.

As transportation is called upon to bear a heavier responsibility in the United States than is the case elsewhere in the world, it should be observed that there is an element of weakness in the functioning of transportation which becomes the point of break under strain and therefore merits particular attention in this country. This is the matter of differential elasticity as between the operations of industry and transportation, which prevents an equalized stretching of the two. For example, when a ton of material passes through a manufacturing plant it means, with due qualifications, that the railroads have hauled a ton of raw material from far and wide and will move a similar weight of products away for distribution. Thus each increment to the volume of manufacture creates a twofold addition to the volume of transportation. Induce a stress of industrial expansion and the stress communicated to transportation is correspondingly magnified. The fabric is mechanical in each case; but the fabric of industry is woven with the maximum of elasticity, while the fabric of transportation is inherently more rigid. Thus, one of the knottiest problems in the whole advance of American industrialism has been involved in the necessity for providing the requisite capacity on the side of transportation. The problem is serious enough at best. But when the item of power in the form of freight-hauled coal is added, the requirement calling for additional elasticity in the mechanism of transportation is almost doubled a second time, and the situation becomes well-nigh impossible to meet. So long as power is provided by means of freighted coal in its present heavy proportion, the transportation of the country is bound to cause serious trouble, if not to break down, in every period of sudden industrial expansion.

The relations of balance, as given above, are not in strict accord with statistical figures. Various other factors come in to qualify the figures, and incidentally to complicate the issue beyond the reach of simple analysis. Nevertheless the contrast noted is indicative of the general situation. The requisite degree of elasticity has not been attainable for transportation, and the lack of it has become increasingly conspicuous with the growth of the industrial order. The tendency has been to provide a surplus of slack in lieu of elasticity by maintaining facilities of transportation in excess of normal requirements. Such a condition constitutes a standing invitation to inefficiency and wastefulness, tending in the long run to nullify the potential advantage of readiness for industrial expansion, and therefore is forecast for failure when put to the test. With industrialism less mature and less aggressive, these matters were less conspicuous, but their untoward propensities under present conditions of growth are becoming steadily more pronounced.

Transportation is the throat of industry, through which all of its materials enter and emerge. Upon the size and flexibility of this opening depends the rate at which industry can grow. Pressure here acts as a throttle; if severe, congestion, choking, even strangulation results. Transportation, then, is crucial. Either we must pay unremitting attention to facilitating transportation by every means available, or else be prepared to see industry retarded and slowed down at this point, with a fall in the scale of living and a change in the color of national advance. So far this country has attempted to meet the issue almost solely by means of railways, and has ignored the bearing upon the matter of the item of power, although this constituent engages over a third of the freight capacity of the country and is a prime contributor to the inelasticity of the transportation fabric as now woven. From a broad point of view it would appear that the transportation problem cannot be adequately solved without due attention to the matter of power.

Conversely, the power supply itself presents a problem of equal magnitude, as without adequacy in this respect the processes of industry are idle. It is notorious that the limiting factor in the supply of power is not a dearth in energy resources, —of which, indeed, this country is amply provided,—but lies in the means for getting the energy distributed to the points of use. The importance of the transportation side of the power problem is reflected in the country-wide system of pipe-lines for the service of petroleum, and the concentration of industry in regions provided with coal,—both concessions to the exigencies of carriage.

Thus, as the transportation problem embraces the matter of power, while the power problem displays itself mainly in the guise of transportation, the two issues merge, and whether viewed from the one angle or the other, the logical objective for an attack is presented in the form of power transportation.

Organized transportation differs essentially from the simple individual act of carrying only in magnitude. The underlying principles are the same in the two extremes. Whether the concern be that of a stone in a neighboring field or a mountain of copper ore a thousand miles distant, effectiveness of transportation involves the same three factors. These are:

1 The employment of the equipment best suited to the task.

2 The advance elimination of superfluous weight.

3 The full utilization of the material transported.

The individual encounters these principles at every move and habitually follows their promptings in conserving his personal efforts. The operation of industry as a whole is also fashioned in conformance with them. The developments in the case of power supply provide the only noteworthy exception. Here the practice is at variance, not merely with one of the principles, but with all three of them. The energy in coal, for example, is not concentrated before shipment, but is hauled in its substantial, bulky form; while the coal at its destination is not used so as to yield anywhere near its full service. With industry in general, conformance with these three principles has been automatic, a natural outgrowth in connection with the development of the various types of operations; with power supply, on the contrary, a sufficiency of natural incentive toward such an outcome has evidently been lacking. It is desirable, then, to seek to determine what is back of this apathy in the exceptional instance of power.

The first of the three principles of transportation, the employment of suitable equipment, involves a community interest. The facilities best suited for bringing to the market the corn raised by one farmer will haul grain from the entire corn belt with equal ease. Moreover, with slight qualification, the same facilities will serve to transport all the material necessities of the region. Hence, there have developed common-carrier systems, represented chiefly by the railways, to which the performance of this function is delegated. These common-carrier systems, it is needless to say, are essential to modern conditions and derive their existence from the community interest which they represent. In consequence, the element of competition, which is the exact antithesis of community interest, is entirely out of place within the confines of such an activity. In the nature of things, accordingly, any response to the promptings of special interests amounts to a violation of a trust. Formerly this was not fully realized, and it has not been long since the evil influence arising from the promptings of special interests within the great common-carrier systems of the country was playing havoc with American industrialism. It is now firmly established, however, that the great arterial complex of transportation is founded on the principle of community interest and must be maintained in scrupulous accord with that principle. In the violation of this trust a common carrier has in itself the power to favor or destroy any industrial enterprise; therefore the method of control must afford the maximum assurance that the trust will not, and cannot, be violated. Thus, the successful application of the first principle underlying effective transportation, from a national point of view, requires a common-carrier system not only adequately equipped as to organization and mechanical facilities, but of public-service integrity established beyond question of doubt.

The second principle of transportation, the advance elimination of superfluous weight, is a matter requiring individuality of treatment throughout. The conditions here are the reverse of those pertaining to the actual facilities of transportation. The responsibility attaches to individual activities; there is no community of interest in the matter; the responsibility may be ignored, but it cannot be delegated. In the realm of industry, competition affords the incentive for meeting this responsibility. The incentive, in general, has been sufficient for practical purpose, and the specific application of this principle constitutes one of the chief interests in the shaping of industrial enterprise.

As power is a mineral derivative, the mineral industries provide a logical field for comparison. Here is found scarcely an instance of consequence where the raw mineral values are not concentrated to their utmost before shipment and where every available refinement of procedure is not employed toward the advance elimination of weight. The whole field of ore dressing has grown up under the incentive of this principle, not to mention the applications to metallurgy in this respect. The only noteworthy exceptions occur in rare connections where competition for the placement of the end products is a negligible factor. Perhaps the most notorious example of failure on this score is afforded by anthracite coal during the war-time stress, when millions of tons of waste slate were permitted to accompany the outgoing shipments of coal from the mines. The same thing was essentially true of bituminous coal during this period; only, as bituminous coal in the natural state is cleaner in respect to slate than is anthracite, the relative proportion of waste hauled was less in the case of soft coal.

The third principle of transportation calls for the full utilization of the material hauled. American economic practice has regarded this, along with the advance elimination of weight, as a matter to be left to industrial determination and application. This policy is natural enough and, in general, works out satisfactorily, for the two principles are complementary. What is usable at the manufacturing end obviously determines what represents value and non-value at the raw-material source; conversely, the degree of separation practicable at the source specifies the range of material for which use is to be sought. The whole epoch-marking development in the field of by-product manufacture finds much of its stimulus in the effort to derive returns from what would otherwise be the waste in transportation. But, with certain notable exceptions offered by some of the large industrial combinations, there is much to be desired and little to be proud of, so far as American achievement in this direction goes. The superfluous transportation that results from the failure at the manufacturing end to make full utilization of the whole range of values held in the raw material hauled amounts to many millions of tons each year. Instances are plentiful where the loss is due to a blind non-recognition of opportunity on the part of the interests directly concerned. But in the main the default rests upon the inadequacy of American economic practice, which relies upon competition and the automatic working of the natural law of supply and demand to bring all good things to pass, neglectful of the fact that in the by-product realm supply is conditioned otherwise than by demand, that pending the creation of a proportionated demand the discrepancy of overweight on the side of supply is rejected as waste.

In such manner have the three principles of transportation developed in American economic practice. In the realm of common carriage, competition has been found to be out of place and is no longer relied upon, community interest taking its place. In the realm of advance preparation, competition has proved effective; and its free operation there is desirable. In the realm of full utilization, competition alone has been unable to achieve adequate results; and the need for constructive help to make competition effective here is coming to be recognized. These principles have registered among mineral resources in the main; they have failed dismally to find lodgment in the field of power resources.

Energy is virtually the only natural resource product susceptible of concentration that is shipped broadcast in the crude condition. The dictates of demand, it is true, still call for a large proportion of the supply in the crude state, and to this extent concentration in advance is obviously impracticable. But the order of requirement is changing rapidly, and even now over one fourth of the call is for the concentrated product,—electricity. Yet, as we have seen, there has been no progressive change in practice to correspond. It is as if our gold supply were shipped in the crude state of its native occurrence for concentration at the market centers instead of at the mine; for whereas the degree of material concentration effected on behalf of gold is considerably over 99 per cent., the attainment possible on the side of energy is a full 100 per cent. There is just one important difference between the two instances. Refined gold is adapted to haulage by the conventional means of transportation at hand, fully as much so, indeed, as the ore from which it is derived. But refined energy is not. It cannot be loaded in freight-cars or done up in express packages. The alternatives lie in providing special facilities of transportation or else hauling the crude material in all its excess bulk for concentration at the points of use, and the choice in practice has uniformly fallen in favor of the second procedure.

The reason for this uniformity is obvious. It is cheaper for the user of energy to rely upon the transportation facilities already at hand, employing them in the movement of the crude bulky material, than to provide himself with special facilities for the transmission of the refined electric derivative. But it does not follow, to be sure, that because the procedure so uniformly followed is individually cheaper, this course is economically preferable. In the absence of railway facilities, for example, it would be decidedly cheaper for the individual consumer to haul his coal from the nearest mine by truck than to build a railway line for the purpose. Yet no one would think of arguing in this case that reliance upon truck haulage is preferable to the opportunities that would be afforded by railway transportation. The issue between electric transmission and railway haulage is precisely similar.

The provision of special facilities of transportation finds its justification in the magnitude of the service to be rendered. Where the item of haulage under view is small in size or restricted in locality, the whole matter need not come up as a broad problem. But the haulage of power in material form amounts to nearly half a billion tons and covers the country. There is no default, then, on the side of magnitude. Special facilities, too, have been provided for oil, the power material next in importance to coal. To serve the ends of this large resource a network of pipe-lines, thousands of miles in aggregate length, is spread over half the country. In this case, however, crude oil is not in the nature of a general utility, but serves a specialized industrial demand centered in refineries. In consequence, pipe-line transportation found its creation and nourishment at the hands of the large private interests at stake. For electric power, on the contrary, there was no such activating interest. Though bulking large, it enjoyed a diverging distributive use quite the opposite of the convergent refinery consumption of crude oil. Moreover, the railways were already established in coal-fields when electricity came on the scene; their presence, therefore, offered scant encouragement to the growth of a more modern type of common carrier. On the contrary, it may be surmised that the whole matter may have been arbitrarily held back by the pecuniary disadvantage that would accrue to the established undertaking in event of change. Indeed, it may well be that this consideration has not been without weight in retarding the electrification of the railway lines themselves. A given railroad, under conditions of active competition, could scarcely be expected to take the lead in giving up such a lucrative item as the transportation of coal. It thus appears that such interests as already occupied the field were inclined to oppose the provision of special facilities for the transportation of energy, while in respect to oil the interests concerned in advancing its transportation were sufficiently strong and organized to overcome the factors inhibiting the establishment of the modern pipeline. Hence, the energy needs of the country are now served by two carrier systems instead of three.

A special type of transportation equipment in the form of electrical transmission lines is urgently needed to serve the energy requirements of this country, but these special facilities may be advantageously established only on the basis of a common carrier. In close analogy to the railways, though in contradistinction to oil pipe-lines, the service to be rendered is strictly distributive and of a public-service order; therefore competition here is out of place to precisely the extent that it is inexpedient in the case of the railways.

The railroads of this country wrought havoc with industrial life until the element of special-interest preference was eliminated and the whole system was placed on a common-carrier, public-utility basis. We may profit in this matter by that experience, and arrange to skip the period of adjustment that proved so costly and disastrous in connection with railway development. The railroads, therefore, provide a warning from which may be determined the status that should be accorded the new development. Hauling coal is a problem of transportation; hauling energy in the form of electricity involves the same range of principles but requires a different set of physical means. In point of fact, the whole advancement is but a further refinement in transportation equipment, just as the modern steel gondola is a refinement of the old-fashioned coal-car.

The railroads themselves have a prime interest in this matter of establishing more facile means for the transportation of energy. Not only are they the chief haulers of energy in bulky form, but they likewise constitute the chief single consumer of this material energy which burdens their lines. The railways burn approximately a fourth of all the coal produced in this country, this item alone representing at least a tenth of their total operating expense. Thus an improvement in energy transportation would not only relieve the railways from a needless burden of bulk haulage, but would at the same time benefit otherwise their operations by giving an impetus to railway electrification, with attendant gain in freight movements by virtue of the greater freight capacity accruing to electrified systems.

The increase in freight capacity that comes with electrification, with its accessory automatic devices that permit an almost solid stream of freight-cars, is startlingly great in view of freight congestions under present arrangements. With proper terminal facilities and electrification it is safe to say that the freight capacity of a system could be multiplied by a considerable figure. It has been recently estimated, for example, that inland transportation in England attains a capacity efficiency of scarcely ten per cent. Notice has frequently been taken in the United States of the anomaly of hauling coal halfway across the continent to lift a train across the Continental Divide, when the topography of the divide is ready to provide for this purpose hydroelectric energy, which itself is susceptible to partial recovery on the down slope by means of regenerative braking. In this connection, the pioneer work of the Chicago, Milwaukee & St. Paul Railway is deserving of the highest commendation for its constructive significance.

It is commonly recognized that one of the weakest features in the industrial development of the United States is the over-accentuated responsibility falling upon the railways; any measure tending to lighten this weight obviously strikes at the roots of a fundamental and important issue. While the consideration may be a digression in this place, a plan for adequate inland transportation in this country is conceived to embrace: (a) airplane service for special mail and for passengers restricted in time; (b) motor-truck service for short-haul freight and in farming districts in coördination with parcel-post deliveries; (c) railway service for normal freight and passenger accommodations; (d) trunk-line, deep waterway haulage for slow-moving and bulky freight; and (e) transmission lines for the delivery of electrical energy from the coal-fields and water-power sites, in coördination with pipe-lines for the transmission of energy in gaseous form.

Under present conditions, to sum up, the power supply of the country is provided chiefly in the form of coal, with fuel oil the mainstay in sections distant from coal-fields, and water-power drawn upon here and there where conditions are favorable to its development. The coal applied to the production of power amounts to nearly half a billion tons, and is hauled chiefly by the railways to its multitudinous points of use, although in many instances as much as a quarter of the supply is there turned into electric power. This method of handling coal imposes a tremendous burden upon the railways, leading to congestion and shortages in periods of business prosperity when the demand for coal enlarges and the quantity of other materials demanding transportation at the same time increases. The use of fuel oil and crude petroleum for purposes of steam raising and the like, which is considerable and represents over half of the total consumption of petroleum and its products in point of bulk, sustains a gross overproduction of petroleum, and in consequence contributes markedly to a premature exhaustion of that resource, with initial effects already in sight. The relative lack of employment of water-power adds to the overburden falling upon transportation in respect to coal, not to mention its bearing upon the portion of coal and oil used to support the delinquency on the side of water-power. It leads, moreover, to an unnecessary centralization of industry with undue differentiation of economic interest, as is apparent in view of the complementary distribution of coal and water-power.

Industrialism has developed upon the basis of the distributive use of coal. The economics of the situation rests in this status, although the technology of power usage has advanced beyond this state. Power stations centralized in respect to the coal-fields and distributing electrical energy to the points of utilization represent the most economical method of coal-power usage. Apparently, such a devolopment has not promised to be profitable to private enterprise; otherwise we should have it. The development is technologically feasible. The lack is due to the fact that the common-carrier systems of the country are equipped for carrying *coal,* not for carrying *energy.* Hence, industrial enterprises find it more profitable to purchase coal hauled by the railways than to provide themselves with special facilities for the transmission of electricity. The railroads, also, have not gone into the matter; hauling coal has been one of their most important and profitable items of freight, which they have been loath to give up; moreover, they have been subjected to a type of Federal control in respect to rates such as would make them stand to lose the benefits of economies in this direction.

Although hindered by legal restrictions growing out of a public sentiment that disfavored any action savoring of commercialization in respect to scenic beauty, water-power has not developed, because of the high cost of money demanded by current financial conditions for water-power projects. As three fourths of the running expenses of a hydroelectric plant is interest money on the heavy investment consequent to development, an interest rate of 8 to 10 per cent. as normally obtaining in the United States places water-power beyond competition with coal and oil in their normal state of overproduction and cheap supply. Such power sites as have developed, aside from those initiated by the Government under war conditions, have been choice examples with such natural advantages of topography and location as to offset the financial handicap. With no change in financial status, water-power cannot develop until coal and oil are skimmed of their cream. In the case of oil, this is imminent, and in the far West but a year or so distant, there merely waiting for the decline of the California oil-fields.

Comparing the two issues of water-power and coal power, which we have reviewed in detail in Chapter VI, we find that the causes which have retarded the development of hydroelectricity and prevented the establishment of carboelectric power-stations at coal-mines are broadly similar. In the case of water-power, the failure is traceable to (a) initial cost and (b) a deadlocked issue between public and private interests; while, with coal, the element of initial cost has been almost equally effective, with a lack of interest, instead of discordant interests, acting as the contributory factor. The provision of suitable transportation will clear up the two retarding influences in both cases.

In the first place, the development of a common-carrier system of electric transmission lines on an adequate basis will nearly halve the interest rate now demanded of projects having to do with electrical development. We have for this assurance the example of the railroads themselves, which have long been accustomed to procure capital at rates of 5 to 6 per cent. The system under view could be given more stability than the railroads have formerly enjoyed, to the gain, perhaps, of even better interest rates than may be calculated from the unqualified analogy. Not only would this stability be inherent in the transmission-line development itself, but would reflect a similar measure of soundness upon the projects concerned with the development of power sites and the establishment of power-plants, so that the field of power operations in its entirety would benefit. The recognition of public backing would transfer the whole matter from the type of investment sponsored by the professional promoter to the realm of securities represented by bonds of a substantial and conservative standing. And since the cost of money is the major expense attached to the development, the reduction of this factor would reflect in increased proportion in the lowered price of electric power. It should be mentioned, also, that in many instances the development of water-power sites involves the provision of facilities for navigation and irrigation. These attendant activities would be in the nature of by-products, so to speak, over the gain to be derived on the score of power, and as such they should weigh in outlay calculations as joint sharers in the expense apportionment. The provision of a lower money cost for water-power development, therefore, would reflect advantages over a wider scope than is embraced even in the broad item of power usuage.

In the second place, a special common-carrier system under public oversight would serve to give the proper temper to the apprehension of the public in respect to surrendering what is now conceived to be its natural rights, thus breaking the deadlocked issue that has so long contributed to the sluggishness of hydroelectric developments; while the apathy surrounding the matter of coal-field generation of electric power would be replaced by conditions making for the profitable establishment of this activity. The public, seeing its interests properly safeguarded, can be counted on for sympathetic support of the movement; while industrial interests in general, being in the business of manufacturing commodities rather than energy, will find it natural to favor any action that would facilitate the supply of energy,—an accessory to their operations,—just as they are interested in any constructive measures that would be likely to ease off the labor problem.

The experience of this country has shown that the conduct of the common-carrier systems must be subject to public oversight. At the same time, it has been amply demonstrated that, for the sake of safeguarding private initiative and business enterprise, this oversight should be called into play as slightly as conditions permit.[1] Applying these concepts to the proposition in hand, we reach the conclusion that while it is necessary that a system of electric transmission lines should be of a common-carrier, public-utility order, for which the railways provide a pattern, the realm of power production offers great leeway for the upgrowth of coördinated but separately constituted activities, thus stimulating initiative and encouraging business enterprise far beyond their present attainments in this field. In this connection, it is worthy of emphasis that such restrictions as may be inherently necessary in correlating the whole fringe of attendant activities with the central enterprise will be overwhelmingly offset by the tremendous opportunities created by the unfoldment.

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[1] While there can be, of course, no universal agreement to premises of this kind, these two conditions are believed to represent fairly the common view of the country in this matter. They certainly involve no violent assumption, for both for some time have been guiding influences in the destiny of the nation.

This type of devlopment will place water-power and coal on an equal footing. In regions where only one is present, that alone, of course, will be used. But in regions where both are on hand, the one rendering the cheaper service will come into play through a process of natural, unhampered selection. Thus the common carrier will coördinate the two resources, so long estranged, and lead to their complementary and balanced development. Adequate transportation has always been necessary to the development of resources; it is a commonplace that no region, however rich, can become of consequence until served by proper carriage. This is no less true with energy. Given suitable transportation, our energy supply is assured.

The final status of a common-carrier system for the transmission of energy cannot be foreseen. The entire problem of transportation is in course of flux, and the special issue of power must be cast into the caldron in which the railway matter is boiling. As the railways emerge, so should power. But with no inclination toward voicing a decision in the matter, it may be anticipated that a special transportation service for power, to fulfil its proper function, will have to be either (1) an integrated activity, privately financed but under public oversight on the basis of a common carrier, and comparable to a railroad company; or (2) if still closer Federal oversight be desirable, a close corporation, in which the Government holds the stock, bearing some analogy to the activities carried on in behalf of the country during the war by the Food Administration and the Emergency Fleet Corporation.

Whatever the details of the solution of the problem of power may be, it is necessary that the undertaking give fundamental consideration to two factors that have been to some extent overlooked: these are "form value" and "resource value." Form value is an intangible quality denoting the broad applicability of the energy form in contrast to its theoretical thermal content as ordinarily expressed in British thermal units; form value involves the consideration of transportation as well as utilization. Resource value is an intangible quality expressing the availability of energy in terms of location and thermal character, and involving the potentiality of chemical control for purposes of multiple production. These rather abstract concepts in relation to the technique of energy development are presented to suggest the complex manner in which energy occurrence, energy transportation, and energy application interweave.

Resource energy as the source of power, heat, light, and chemical work is the basis of industrial activity and social advancement. The quantity of energy required in the United States has grown to such stupendous proportions that its provision in the customary manner is becoming increasingly difficult, with growing uncertainties of supply and rising costs. A complicated civilization is dependent upon a system of energy supply which has failed to adapt itself to changing circumstances with sufficient rapidity, and in consequence industrial and social progress is building upon a failing and obsolescent foundation. The need is for adjustment in energy form to the end that greater efficiency in utilization and transportation shall be obtained, and a full measure of resource value achieved. This accomplishment is predicated upon a point of view that will face the problem in its entirety and subordinate the technology of performance to the economics of service.

CHAPTER IX

THREE-DIMENSIONAL TRANSPORTATION

GASOLINE is responsible for the most significant mechanical development of the twentieth century, the internal-combustion engine. The growing use of this device for generating power, with its great efficiency and adaptability to small movable units such as the automobile, has colored the whole face of modern civilization. Because of it, a wholly new type of automotive transportation has grown up, at a time when the long-established methods of cumbersome, coal-energized haulage were beginning to impose a serious restriction upon the growth of industrialism and centralization.

The automobile, of course, first by its novelty and later by its wide appeal, has been the prime mover in the automotive development. It would appear to be unnecessary to particularize as to the social value of the automobile, as this matter is common experience. It may be said, however, that apart from its use purely as a luxury the automobile has served to enlarge the possibilities of modern life, not merely by giving pleasure but by improving opportunities for physical and mental recreation, social contact, and business activity, with no small contribution toward facilitating the livableness of the modern city. The automobile has gone far toward solving the problem of personal transportation.

An important outgrowth of the automobile development has been the motor truck, now used in great numbers for city and suburban delivery service, and coming into prominence in the more populous country districts as an efficient agent for short-haul freight. The possibilities of the motor truck are still largely unrealized; its continued extension may be expected to replace largely the short spur line of the railway; and in connection with the growth of a network of good roads, a country-wide auto-truck utilization will furnish an efficient feeder system to the trunk transportation channels of the country. In respect to the prompt delivery of farm produce, whether to railways or directly to towns, the motor truck has an exceptionally useful opportunity. The whole problem of food supply, indeed, is closely bound up with the matter of adequate facilities of transportation, appropriate use of mechanical power, and fertilizers.

The tractor for farm use is a more recent development than the motor truck and the growth in its utilization during the past few years, especially in the Middle West, has been rapid. Coming into play at a time when the national food problem has taken on a world-wide aspect, the tractor assumes the utmost present importance, while the future demands an extension in its use such as may be expected largely to relegate to the past the old-fashioned methods of hand-power and horse-power tillage. Indeed, upon the growing use of mechanical power upon the farm by means of the tractor, the motor truck, the stationary engine, and the automobile—all dependent upon a cheap and adequate supply of motor fuel—the food supply of the future turns. Farm work must be made more agreeable and more efficient if a growing population is to be fed.

The most sensational and radical development in the entire field of transportation, however, is aërial navigation. Under the keen competition developed during the war, such remarkable progress was made in flying technique and mechanical advance that the problem of air transportation may be said to have been virtually solved. Already the Atlantic Ocean has been crossed by both aëroplanes and dirigibles propelled by high-speed motors. The future possibilities of the flying art no one can foresee. But commercial developments are under way for the manufacture of a growing quantity of aircraft, and the newborn industry is confident of a remarkable development of this field.

Thus transportation has been freed from its old limitations imposed by tracks; and the country is dotted by millions of self-propelled vehicles following all directions at will, while the air is plowed by craft free to pursue their way in three dimensions. The sudden projection of three-dimensional transportation upon the scene is the culminating surprise of our material civilization.

Back of the wide-spread utilization of the automotive engine stands a great industry engaged in the manufacture of automobiles, motor trucks, tractors, and aircraft. Starting scarcely two decades ago, this activity has grown until it now represents the third industry, in point of financial value and importance, in the country. In 1920 motor vehicles of all kinds to the number of 2,240,000 were manufactured in the United States, having a wholesale value of $2,136,000,000. By virtue of the kind and quantity of labor employed, of its ramifying sales agencies and extensive advertising, and in turn through its use of steel, aluminum, nickel, rubber, leather, wood, and other raw materials, the automotive industry extends its roots throughout much of the industrial fabric of the country.

The growth of the automotive industry has been phenomenal. Approximately nine million automotive vehicles are in service in the United States in 1921, and at the present rate of expansion nearly two million are being added yearly. The rapid development of the automotive industry has so increased the demand for motor fuel that the ability of the fuel supply to keep pace has come into question. The meaning of the growth of the automotive industry in terms of fuel is shown graphically in figure 27. The construction program of the automotive industry, moreover, in the long run affords no prospect of let-up in the pressure of fuel requirements. On the contrary, the injection into the situation of a notable capacity for truck production introduces an element that bids fair to overshadow even the tremendous automobile demand, while the item of tractor manufacture looms ahead with a fuel significance scarcely second in importance. And the

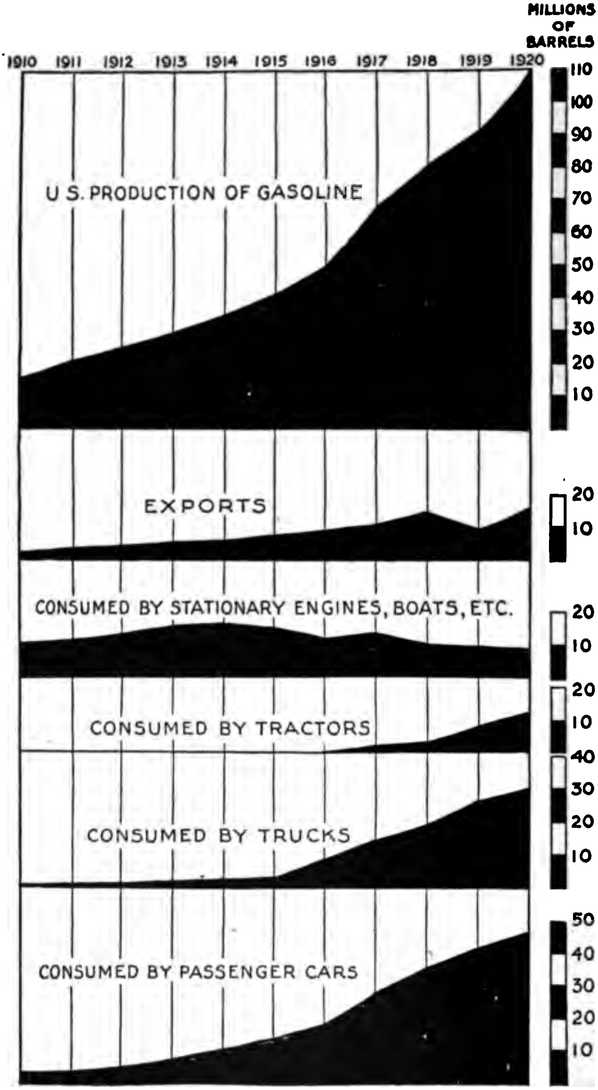


Fig. 27. Production and consumption of gasoline in the United States.

production of aircraft, with their high fuel consumption, is scarcely under way. If the drift of these matters be projected into the future unabated, it is evident that the supply of motor fuel will have to be doubled every few years. The automotive industry is young and vigorous, and its continued expansion will place an unexampled burden upon the motor-fuel resources of the country.

The supply of motor fuel is dependent upon the production of crude petroleum. In 1920 the output of this raw material in the United States was nearly a half-billion barrels. Most of this quantity was refined to produce gasoline, kerosene, fuel oil, lubricating oils, and various by-products, in the proportions shown in figure 28. Gasoline, of course, is the predominant motor fuel in use in this country; kerosene is coming into prominence as a motor fuel, although a small part only of the output as yet finds such application; fuel oil, which bulks larger than gasoline and kerosene combined, is mostly employed for firing steam boilers and in metallurgical plants, although a trifling quantity is used in Diesel engines and a small fraction is converted into gasoline by a process of pressure distillation known as "cracking."

In view of the dependence of the automotive industry upon petroleum, the magnitude of the reserve, or unused portion of the resource, becomes a matter of considerable interest. While

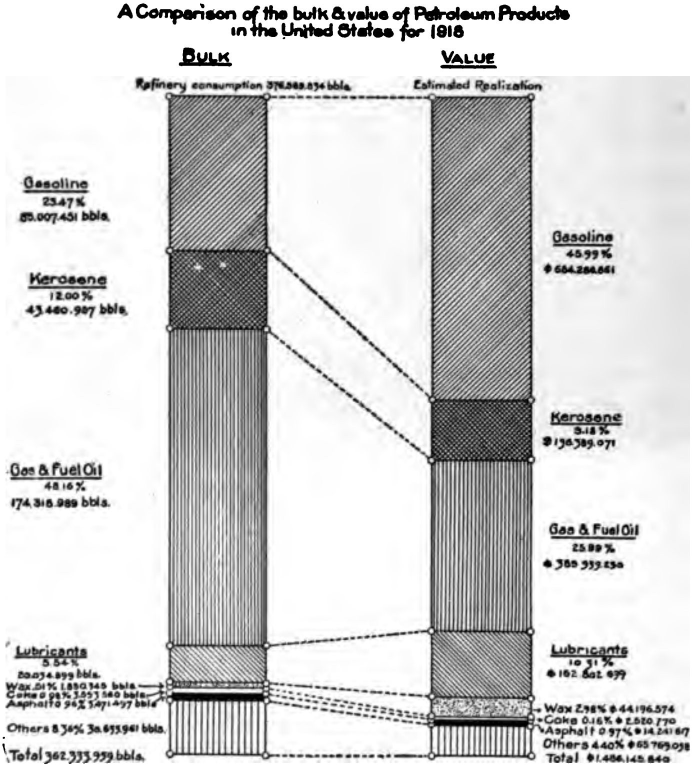


FIG. 28. The relation of gasoline to the other products of petroleum.

unmined petroleum, like other minerals not exposed to sight, cannot be inventoried with a nicety of exactness, the proven and prospective oil-fields of the United States are nevertheless so broadly known that the petroleum reserves may be estimated within a very reasonable margin of error. Such estimates, based on extensive and rigorous engineering data, have been made by the United States Geological Survey in 1908, in 1915, and again in 1919, with results shown in figure 29. There are two significant features of these estimates: the small size of the reserve, which approximates six billion barrels in 1921; and the fact that in the past ten years, despite an exceedingly aggressive campaign of oil exploration, the decrease in the reserve has exceeded the addition to the reserve through new discoveries. Those who therefore count upon the discovery of new oil deposits materially to affect the basic situation overlook the fact that already for ten years new discoveries have been failing to do so, notwithstanding the sensational aspects of new developments when viewed separately.

Compared with the large and rapidly increasing annual draft upon this reserve, the supply seems startlingly inadequate to sustain for any satisfactory period of time the motor-fuel situation as it now stands. Moreover, it is well known, because of greater drilling necessary, that

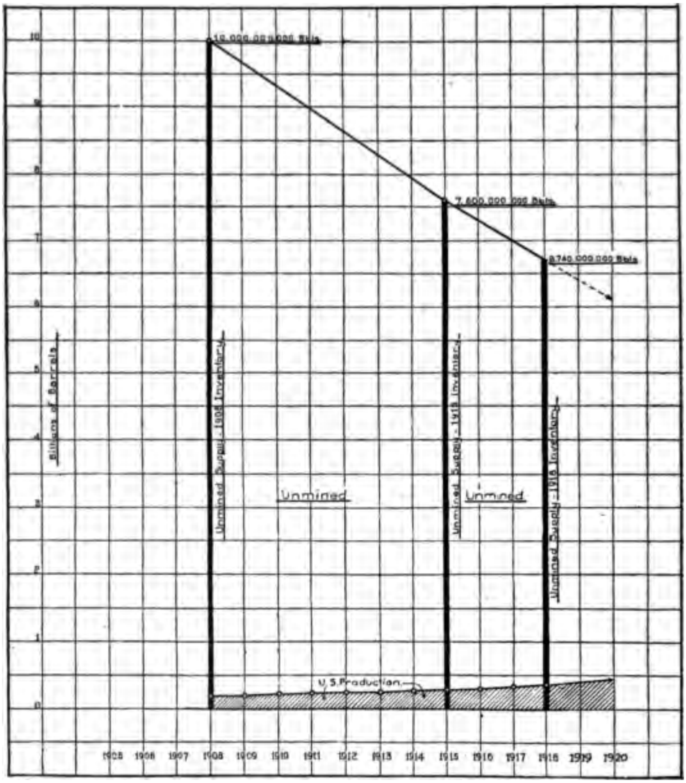


FIG. 29. Inventories of the unmined supply of petroleum in the United States made by the U. S. Geological Survey.

petroleum may be mined only at increasing cost and with increasing difficulty as the resource is depleted. It is already a common belief among petroleum engineers, that the oil output of the United States has reached its maximum, and the end of the present era of flush production in Mexico is in sight.

We may reduce the petroleum situation to a per-capita basis, for readier visualization, as follows:

PETROLEUM RESERVE OF THE UNITED STATES CALCULATED TO A PER-CAPITA BASIS[a]

	Per-capita rate of production in 1920	Mined from 1859 through 1920	Underground in 1921 and available under present methods of mining
Petroleum...	4.4 barrels	54 barrels	59 barrels

[a] The figures are given in round numbers and are based on a population of 100,000,000.

It is evident from the foregoing data, based on the accumulated knowledge of hundreds of workers in petroleum geology, that an imposing proportion of the petroleum supply is used up. But this relation does not tell the whole story; the per capita consumption of petroleum to say nothing of population, increase is growing from year to year, so that a continuation of the present tendency would exhaust the petroleum remaining in an alarmingly short period of time.

This aspect of the situation is depicted graphically in figure 30. With no pretense to prophecy, the diagram expresses the situation that faces the country to-day, and the most generous

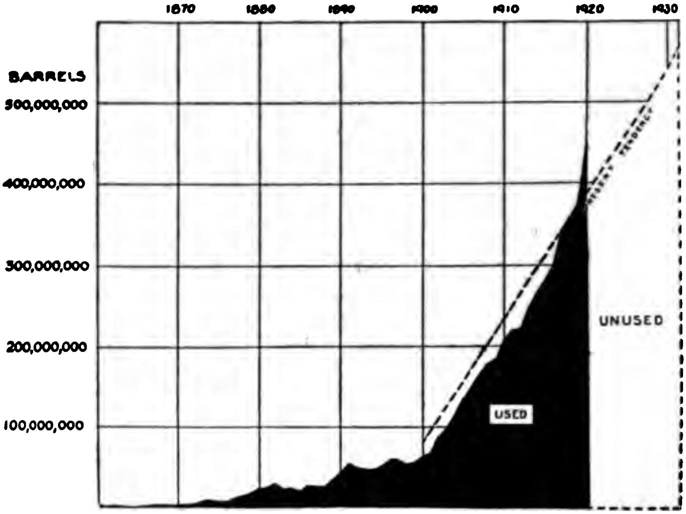


FIG. 30. Chart showing the present tendency of the United States in respect to its unmined supply of petroleum.

allowance of margin to cover possible underestimates of future discoveries does not change materially the nature of the issue. A big fraction of the domestic petroleum is gone; whether that fraction is one-half, as present knowledge indicates, or is on-third or even one-fourth makes no difference in the consideration demanded by the situation. The fact remains that the size of the fraction has meaning to people using petroleum to-day and therefore represents an economic factor that must be reckoned with now.

It is, of course, very evident that the present tendency cannot persist to the point of even approximate exhaustion, because conditions naturally arising, such as price increase, growing imports, and others, will serve to relieve the tension and thus spread the remaining supply over a greater number of years. (See figure 31.) So

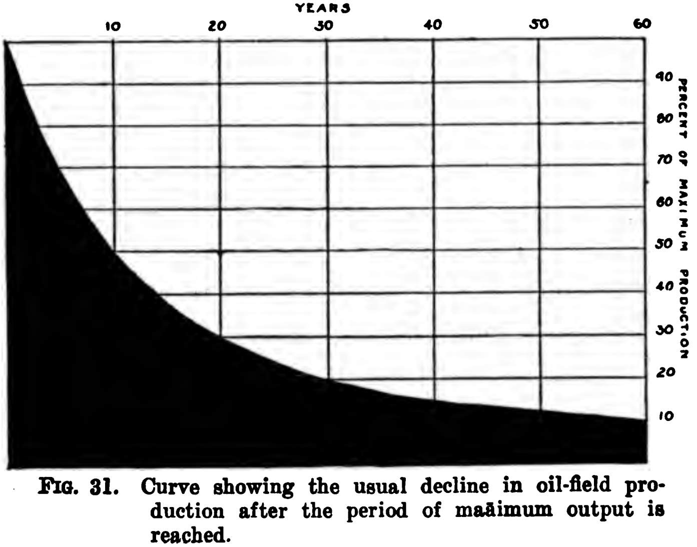


Fig. 31. Curve showing the usual decline in oil-field production after the period of maximum output is reached.

(After Ralph Arnold.)

despite its sensational character, the physical exhaustion of the petroleum resource is a matter of academic interest purely. But of practical importance is the period of economic stress that is ushered in when the resource faces a greater demand than it can fill in the customary manner. That is a period of readjustments to meet the new conditions, and arrives far in advance of physical exhaustion.

As a matter of fact, local adjustments are constantly under way, as petroleum fields reach their climax of production and pass into a period of decline. Each field forecasts the history of the resource in its entirety. (See figure 32.) These local adjustments affect the industry in the way of causing geographic shifts in activities, but they have so far had no national effect, because youthful fields have heretofore been ready and able to sustain the shifted burden. But obviously a limit must eventually be reached when an adequate array of youthful fields will be lacking. A consideration of the present situation, in this light, brings forth the realization that such a dominant proportion of our petroleum supply is drawn from the Kansas-Oklahoma and California fields, that their decline can scarcely expect compensation, without development of other fields to a degree to

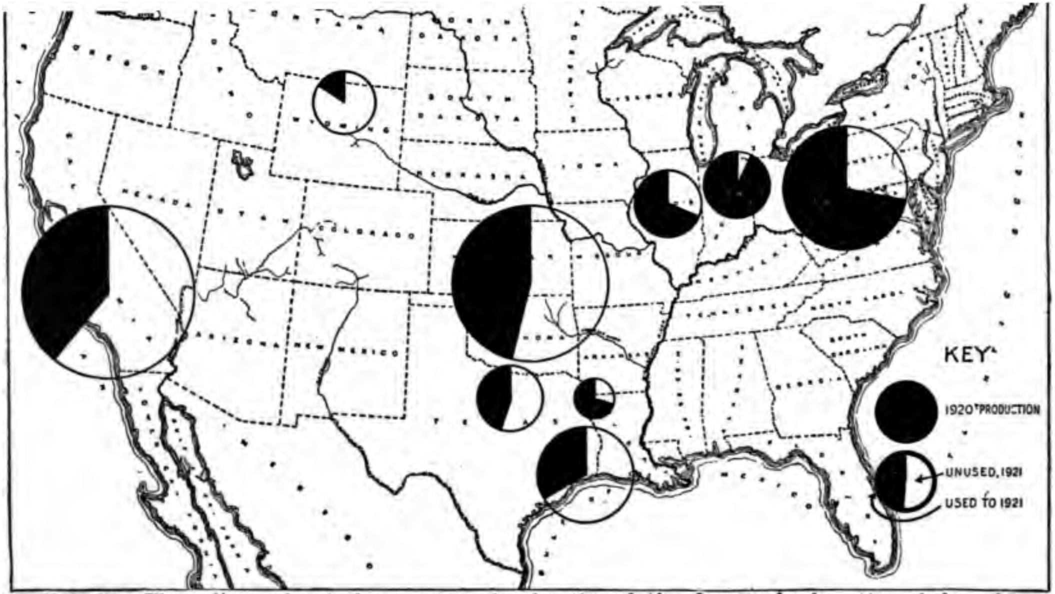


FIG. 32. The eclipse of petroleum (map showing the relative degree of exhaustion of the principal oil-fields of the United States).

which there is no prospect. It is generally conceded, too, that these two fields have well nigh, if not already, reached their productive climax.

It would appear, therefore, that entirely apart from the size of the petroleum reserve, the dependency upon a cumulative oil-field development presages a time, soon to arrive if not already here, when the present rate of production can no longer be sustained in its full vigor. Just so soon as the aggregate output is compounded of senile and youthful fields, with the latter no longer in the ascendency, the resource as a whole will pass inevitably into a period of slowing and more costly production, even though the resource is yet but half exhausted. The period of economic stress, then, waits merely on this concatenation of circumstances, by no means upon a marked physical exhaustion of the resource.

At the same time that the output of crude petroleum in the United States is approaching its maximum, with a limited reserve ahead to support the future, an additional stress between supply and demand has come to a head. This additional stress is involved in the fact that the demand for gasoline has been increasing more rapidly than the rate of increase in the production of crude petroleum. The differential increase as between the raw material, petroleum, and its principal product, gasoline, may be shown graphically by plotting one fifth of the domestic output of crude petroleum, the average *natural* gasoline content, against the actual production of gasoline. (See figure 33.)

It may thus be seen that, until recently, crude petroleum was mined in gross excess of the quantity necessary to provide an ample supply of gasoline. Much gasoline in consequence was unrecovered from the crude petroleum brought into use. This potential gasoline represented "slack" in the situation. During this period, expansion in gasoline output was readily effected merely by subjecting a growing share of the crude output to refining. Although for ten years the rate of increase in gasoline production has exceeded the rate of growth in the production of crude petroleum, no stress was felt until the gasoline "slack" began to run out around 1917.

At present virtually all the easy-to-extract gasoline is removed from the crude petroleum mined, and the motor-fuel demand is not filled by the quantity obtained. The additional supply necessary to avoid a shortage is obtained by roundabout means, such as cracking fuel oil into gasoline, lowering that volatility of gasoline which

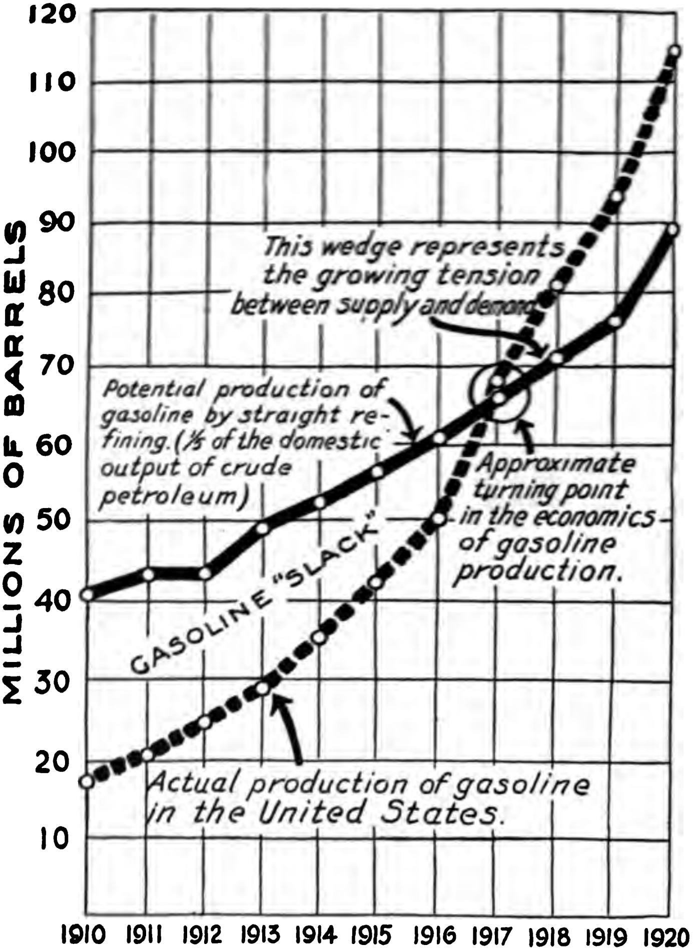


FIG. 33. Chart showing the tightening up of the gasoline supply of the United States.

(After Automotive Industries)

permits a larger percentage (at the expense of kerosene) to be extracted from a given quantity of crude petroleum, and recovering the gasoline suspended in natural gas. These expedients are recent developments, and are being called more and more into play by the rapidly expanding demand for gasoline. In the absence of conspicuous "slack" within the crude supply, the expansion in output of crude petroleum has ceased to be adequate to accommodate the situation.

In short, as the situation is shaping up, the demand for gasoline is increasing more rapidly than resources and means are being developed to provide this product. Accordingly, a gasoline shortage, accompanied by a rise in price, is a prospect to be anticipated, if no means for relief are brought into action. A marked rise in the price of motor fuel, if not conpensated, will retard the development of the automotive industry and hold back the whole field of activities dependent upon its unbroken advancement. Such an outcome would affect a remarkably wide range of interests. The automobile-owning public, farmers, business activities using motor trucks, and the automotive industry with its ramifications—or, expressed in another way, transportation, food production, and a large branch of manufacturing

—all have a vital concern in this matter. Under restriction in supply or price of motor fuel, these various activities would suffer a progressive narrowing in scope which would be the antithesis of the continued progress that their importance urges.

It is, therefore, of interest to review rather critically the various means whereby the supply of motor fuel may be increased, with a view to determining if the tension now developing between supply and demand has a likelihood of relief other than through an advance in price. The production of motor fuel may be augmented by increasing the output of crude petroleum, by improving the means for manufacturing gasoline, by developing supplementary fuels, by adapting the engine to burn fuels less specialized than gasoline, and by increasing the fuel economy of the engine.

The output of crude petroleum cannot be expected to increase sufficiently to meet the growing burden imposed by the gasoline demand. The domestic production of petroleum approximately reached its maximum in 1920, without contributing more than five sixths of the petroleum consumed in the United States, the difference being made up by imports from Mexico. The domestic output, therefore, is already lagging, and we are becoming increasingly dependent upon the deposits of Mexico, Central America, and South America. But apart from uncertainties as to the extent and political stability of these foreign sources of supply, they are undergoing hasty exploitation as sources primarily of fuel oil, for the most part are rather low in gasoline content, and cannot be counted on to offer more than partial and temporary relief to the motor-fuel situation. The present rapid rate of increase in gasoline consumption cannot be long sustained by the petroleum resources in sight.

Besides crude petroleum, the only source of gasoline is natural gas. A small but growing quantity of gasoline is now extracted from the natural gas produced in the United States. The gasoline so obtained is highly volatile with a low end point and is used for blending with gasolines of low volatility (sometimes called naphthas) and with gasoline made by processes of cracking. Natural-gas gasoline—or casing-head gasoline as it is frequently called—is of greater economic importance than its relative volume would indicate, because it is employed for "sweetening up" the portion of the gasoline supply which would not be readily available without its use. In rough terms, a barrel of natural-gas gasoline enables two barrels of commercial gasoline to reach the consumer.

While the output of gasoline made from natural gas has grown rapidly, its absolute contribution to the gasoline supply has been relatively small; nor is it likely to assume much more prominent proportions (around 10 per cent. of the total supply), since the natural-gas industry is displaying a slowing rate of production. Therefore the aid that the gasoline supply may expect from this source has probably almost reached its maximum in a relative sense.

Of the gasoline extracted from crude petroleum, the bulk is composed of volatile hydrocarbons originally present in the crude and removed by ordinary processes of distillation. The gasoline obtained in this manner may be termed straight-run or natural gasoline. If the country's production of crude petroleum for the year 1920 were averaged, its natural gasoline content would be around 20 per cent., or roughly ninety-one million barrels. Not quite all of this natural gasoline was extracted, yet the domestic production of gasoline in 1920 was one hundred and sixteen million barrels. Counting in the contributions from natural gas, a discrepancy of some eighteen million to twenty million barrels is to be observed. This difference was made up mainly by cracked gasoline.

Cracked gasoline is made from a special variety of fuel oil, called gas oil, by processes of distillation employing high temperatures and pressures which partly break down or crack the material into gasoline. Such methods of distillation are known as pressure or cracking distillation, and the growth of these methods has already augmented the gasoline supply by something like 15 per cent. of the total. This type of gasoline is not used directly as such, but is blended with straight-run and natural-gas gasoline.

There is a good deal of misunderstanding regarding the possibilities of cracking processes, partly because the operating details are carefully guarded and little exact information is generally available on the subject. There has been a tendency, therefore, superficially to appraise cracking as a method for converting fuel oil into gasoline, without reference to the physical and economic limitations of the process. The common line of reasoning in this respect is to take the country's output of fuel oil—which is roughly two hundred million barrels—and to assume that this quantity can be quickly converted into gasoline, as demand increases, by simple additions to refinery equipment.

Cracking is the most important single factor capable of enlarging the supply of gasoline from a given quantity of crude petroleum, but while cracking processes are legion, very few have attained commercial success, and those which are of practical importance have been unable as yet to attain a working efficiency much higher than 40 per cent. Also, only certain light grades of fuel oil (so-called gas oil) have as yet proved suitable as a raw material. While, of course, the art of cracking may be confidently expected to advance, the fact must be faced that under present conditions of that art less than 40 per cent. of the fuel oil supply of the country, even granted it could be diverted to such treatment, represents potential gasoline.

On the whole, therefore, while highly significant additional contributions of gasoline may be expected from the avenue of cracking, an unlimited expansion cannot be counted upon on this score, and it is questionable whether cracking can be expected to expand at a very much greater rate than has characterized the process in the last few years.

It is common notoriety that gasoline during the past few years has been becoming heavier and less volatile in quality. In this way, the total supply of gasoline has been increased at the expense of the lighter fractions of kerosene which went the way of motor fuel instead of illuminating oil. This outcome is the normal economic response to a growing demand which the increase in crude production and the increments from natural gas and cracked fuel oils were unable to meet unaided. The virtual limit to the enlargement of the gasoline supply in this manner, however, is set by what the standardized automotive engine will accept in the way of fuel; which is to say that this avenue of relief is wholly in the hands of the engine-building industry.

There are a number of supplementary fuels which may be drawn upon to help out gasoline, and considerable attention has already been drawn to these alternate motor fuels. The supplementary fuels of promise are kerosene, fuel oil, benzol, alcohol, shale-oil distillate, and composite fuels.

Kerosene, which sold in 1920 for about two thirds the price of gasoline (see figure 34), is available for use directly as motor fuel or through addition to the gasoline supply which is thereby decreased in volatility. There is a growing tendency, especially in the tractor industry, to use kerosene directly as a motor fuel, but thus far its use in the gasoline engine cannot be said to have given generally satisfactory results. Cracking processes are under development which employ kerosene as their raw material, but the

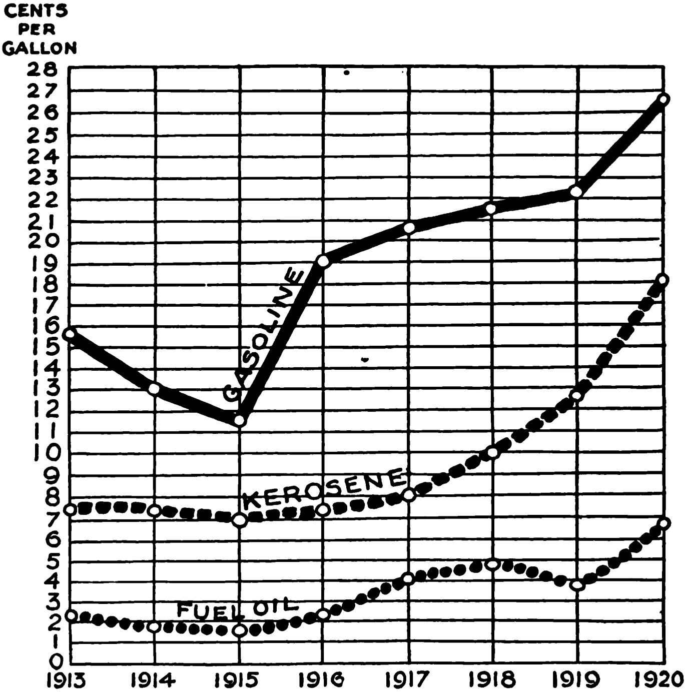


FIG. 34. Average wholesale price of gasoline, kerosene, and fuel oil in the United States.

commercial practicability of such processes remain largely to be established; up to the present certain grades of fuel oil represent the dominant raw material from which cracked gasoline is produced. The indirect use of kerosene through incorporation into the gasoline supply has already appreciably reduced the output of kerosene proper, but the engine in current use interposes a barrier to a practical extension of this expedient to embrace the entire kerosene cut.

Fuel oil is available as motor fuel directly in heavy-oil engines of the Diesel or semi-Diesel types, indirectly through the avenue of cracking into gasoline, and directly in the current type of engine through the medium of gasification by means of heat. As fuel oil is now almost exclusively used for steam raising and gas manufacture—purposes for which coal would suffice—virtually the entire supply can be commercially captured by the automotive demand. Fuel oil is due for a rapid diversion to transportation purposes, and competition will rapidly develop between cracking, on the one hand, and direct use, either in heavy-oil engines or upon gasification in light motors, on the other.

Fuel oil has come into extensive use in the United States, especially in the far West, as a substitute for coal. It is more convenient than coal and is therefore adopted by industries wherever its price is low enough to permit its use. About half of the petroleum currently produced is used as fuel for steam raising, this portion including the crude petroleum employed for fuel purposes and the fuel oil proper turned out by petroleum refineries. The whole southwestern portion of the United States is wholly dependent upon fuel oil; shipping and naval activities on both oceans draw much of their energy from this substance; and of late years a growing number of industrial operations of the eastern half of the country have come to use this convenient fuel. Its employment in the latter manner cannot be sustained, in view of the slowing rate of petroleum production and the counter demand that will come in increasing measure from the further development of "cracking" practice in refining and from the wider adoption of the Diesel type of internal-combustion engine. It will soon be necessary, therefore, to bring coal and hydroelectric power to the aid of a growing number of those activities now dependent upon oil fuel.

The fuel-oil problem carries peculiar significance to the Southwest, for most of the far-western railroads and industries and much of the

Pacific coast shipping are utterly dependent upon fuel oil for energy. Because of the prolific oil-fields of California, which came into play at the beginning of an era of great industrial growth and the distance of the Pacific region from important coal-fields, petroleum in that section is both coal and oil, so to speak. It cannot long play the double rôle. The far West must either turn to coal, hauling much of it long distances, or else develop cheap electric energy from the streams of the Sierra and coast ranges. It so happens, however, that over one-third of the available water-power of the country is to be found in the States of California, Oregon, and Washington, ready to release oil from its crudest use as soon as an adequate policy of national water-power administration comes into play.

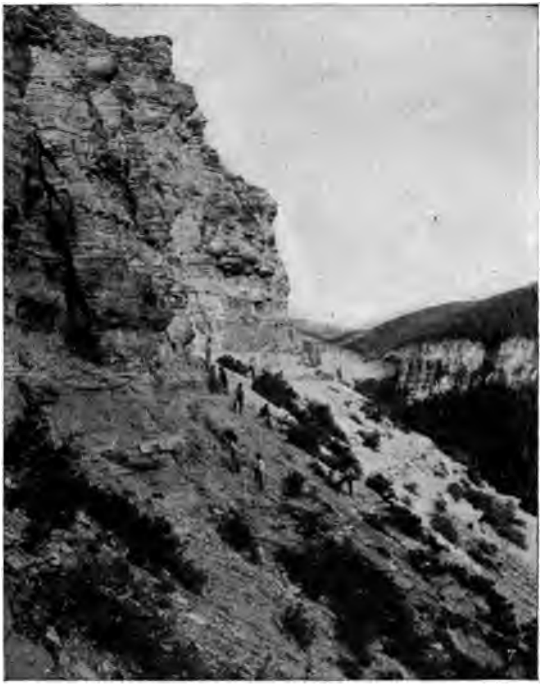
Fuel oil offers such a range of advantages over coal for ocean shipping, and such high economy can be effected through the use of the heavy oil motor, that the world's shipping is rapidly turning or planning to turn to this ideal fuel. In view of the limited nature of the resource, this tendency, once under full swing, may be expected to bring an advance in price such as will largely withdraw this product from its industrial-fuel rôle, especially since the demand for gasoline at the same time will be pulling more and more heavily upon fuel oil through the avenue of cracking.

The availability of fuel oil as a general motor fuel, whether directly or as the raw material for the manufacture of gasoline, is complicated by the tremendous prospective upgrowth in the use of the marine motor burning fuel oil,—a development that will encroach more and more upon the fuel oil supply at the same time that fuel oil is coming to be needed by automotive agencies on land. The competition in prospect between automotive transportation on land and on sea offers a perplexing problem, whose ultimate solution would seem to lie in the reversion of ocean shipping to coal as its energy dependency.

With increasing price of gasoline and the possibilities of an ultimate stringency in supply, more and more attention is naturally turning to compounds which may be made from materials other than petroleum to replace gasoline. In this field the wildest statements prevail and the utmost caution is necessary for appraising the true situation. It should always be borne in mind that motor fuel is required in such tremendous quantities that the problem of developing a substitute of the requisite volume must be a matter of many years, even granted an adequate resource and appropriate technology. The products which have immediate significance in this connection are benzol, a by-product from the distillation of bituminous coal, and alcohol, made from organic materials. Unfortunately there are serious limitations to what may be expected from either source. The production of benzol depends upon a costly and elaborate chemical industry which has thus far grown but slowly and has little chance for ultra-rapid expansion in the immediate future. The output of benzol at the present time is about fifty million gallons a year, which is only 1 per cent. of our gasoline requirements; and even if the benzol were extracted from all the bituminous coal brought into use, the supply would fall far short of our present needs. Alcohol likewise has limitations. In the first place, the supply of materials available for the manufacture of alcohol is limited, and in the second place, there are legal restrictions to the free output of alcohol which stand in the way of rapid development of the industry, and which at present are actually retarding this matter. The present output of industrial alcohol is roughly of the same order of magnitude as that of benzol, and while the output of alcohol may be expected to increase, there is no possibility whatsoever that quantities running up into hundreds of millions of gallons can be easily or quickly brought upon the market.

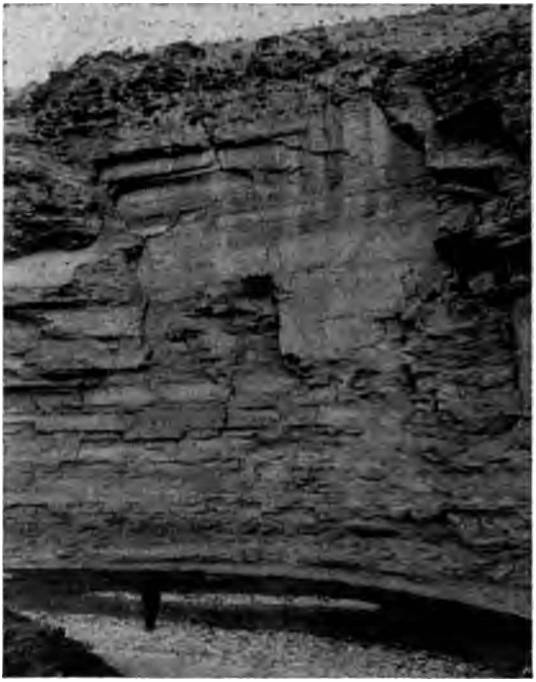
Effective service in the internal-combustion engine is possible with either benzol or alcohol, especially if these products are blended with petroleum products. Certain fuels of this general type have already met with some success and every encouragement should be given their future development. On the whole, however, benzol and alcohol hold better promise as blending agents in connection with petroleum products than they do as single fuels; but the utmost that may be expected from them in the calculable future is that they will augment by a small percentage the total supply of motor fuel.

The occurrence in many parts of the country, especially in Colorado, Utah, and Wyoming, of immense areas of black shale, capable of yielding upon distillation appreciable quantities of an oil analogous to petroleum, has attracted considerable attention of late and offers a prospective source of motor-fuel. (See figures 35 and 36.) Oil-shale, indeed, is generally looked upon as the logical successor to petroleum, which will come into commercial development as soon as the richer petroleum resource needs a supplement. Shale-oil cannot be produced as cheaply as petroleum at the present price level of the latter, although it is expected by many that moderate price advances over the present scale may bring shale-oil on a parity. Considerable preliminary developments have already taken place over the past few years in Colorado and Utah particularly, but the pro-



(Photograph by courtesy of Denver & Rio Grande Railroad.)
FIG. 35. A supplement to petroleum: cliffs of oil-shale near Grand Valley, Colorado.

gress of the new industry has been slow. At best, even granted a distinct need for output, the development of a large production of shale-oil must be a matter of many years, because of the extensive mining operations and large distillation plants that must come into existence as a preliminary.



(Photograph by courtesy of Denver & Rio Grande Railroad.)

FIG. 36. A great wall of oil-shale near Watson, Utah.

While oil-shales have only recently come into notice in the United States, a similar resource has for many years been profitably exploited in Scotland, New South Wales, and France, where nature has been less bountiful with petroleum; while in Germany the extraction of oil from low-grade coal and other bituminous materials has become a well-established undertaking. A comparison of the domestic prospects with the foreign practice in the way of yield may not be out of place.

GENERAL COMPARISON BETWEEN OIL-SHALE OF SCOTLAND AND OF COLORADO, UTAH[a]

Average yield from 1 ton oil-shale	Scotland	Colo. and Utah	Use
Oil ....gallons	24	50	Substitute for petroleum.
Ammonium sulphate, pounds	34	17–25	Fertilizer; nitrogen products.
Gas ....cubic feet	2,000	3,000	Fuel.
Shale residue ....pounds	1,600	1,500	Brickmaking; cement; road making; possibly for extraction of potash. Undeveloped possibilities.

[a] Data generalized from various sources, including Bulletin 641-F, United States Geological Survey, 1917; Bacon and Hamor, *The American Petroleum Industry*, 1916; Hearings on oil-shales before the House Committee on the Public Lands Feb. 26, 1918; personal communications from David T. Day and Russell D. George. The figures for Colorado and Utah are provisional rather than final, but are believed to be conservative.

While the most conspicuous oil-shale areas recorded in this country are in Colorado, Utah, and Wyoming, with the most immediate interest centering about those of Colorado, other oil-shales are found in Nevada, California, Montana, Arizona, Oregon, and in many of the Central and Eastern States,—aggregating an immense area and representing a potential source of oil sufficient to supply this country for hundreds of years. (See figure 13, page 93.) Of course it is evident that much of this shale has prospective interest merely; but there are certain beds farther east in close association with coal or other mineral deposits, which offer themselves as productive possibilities under present conditions in connection with a coordinated extraction of a range of values. Still other possibilities open up in connection with the production of oil, gas, and by-products from cannel coals; the whole matter in this wise passing over into the realm of by-product coal distillation, whose possibilities have been developed in earlier pages. On the whole, however, significant additions to the motor-fuel supply from oil-shales are still a number of years distant, and the whole matter cuts little figure in the immediate problem, however large ultimate contributions may turn out to be; although such volatile shale-oil distillates as may come on the market may be expected to find their way into the motor-fuel supply in the form of composite fuels, in much the same fashion as benzol and alcohol.

Heretofore, automotive transportation has employed single fuels, chiefly gasoline. With the approach of supplementary fuels, and with progress in fuel research, the matter of mixed or composite fuels is assuming considerable interest. If it becomes necessary for the motor-fuel demand to be met by two or more fuels of diverse sources, the question of distribution will assume added importance, as to whether those fuels may be more advantageously marketed separately or as a blend. It may turn out that a virtue can be made of a necessity, so to speak; for initial researches on mixed fuels have already gone to show that certain mixtures may yield more favorable results than the components in severalty. Indeed, it is thought by some that results of far-reaching significance may be attained by intensive research in this direction following the trend of the economic situation in respect to motor-fuel production.

Since automotive transportation has developed and become standardized on the basis of gasoline, the significance of the various fuels coming into sight to supplement the gasoline supply does not depend upon the individual merits of the fuels so much as upon their capacity to enmesh with the existing situation. A study of individual fuels, therefore, will prove misleading if not accompanied by an appraisal of the relationship that each bears not only to gasoline but to all other fuels that have potential motor use. This is one of the features which renders the motor-fuel problem so intricate and so elusive if viewed with its various parts dissociated. It cannot be too strongly emphasized that the merits of any single factor in the situation, whether it be a process such as cracking, a new fuel undergoing development such as benzol or alcohol, a fuel in the offing such as shale-oil distillate, or new types of mixed fuels, cannot be evaluated unless cross-referenced with respect to all counter developments falling under its sphere of influence.

Having viewed the motor-fuel situation from the point of view of fuel, we may observe the situation from the opposite point of view of the engine. Automotive transportation, at present, is wholly dependent upon the internal-combustion engine, which was devised for the consumption of coal-gas but came into prominence only after its adaptation to the employment of gasoline.

The presence of an oil industry, already grown to large proportions on the basis of kerosene, rendered available an ample supply of gasoline which formerly had to be removed from the kerosene but enjoyed no favorable market of its own. Born under easy conditions of fuel supply, the automotive industry has enjoyed this advantage until very recently.

This era of gasoline surplus, when gasoline remained unextracted from a significant share of the output of crude petroleum, may also be termed the era of engine independence. The expansion in motor-fuel demand was then met by running a larger share of the crude petroleum through refineries, and the gasoline supply was maintained without sufficient change in quality to dictate adaptations in engine design. During that time, engine progress lay largely in the direction of refinements of quality,—flexibility, power, convenience, etc.. Fuel was standardized—a volatile gasoline—and the engine was independent of other fuel considerations. In consequence, the internal-combustion engine of the type currently in use in the United States is very uneconomical in respect to fuel. Under the ordinary conditions of day-in and day-out service, scarcely five per cent. of the theoretical value of the fuel is extracted. The engine has not developed rapidly in respect to thermal efficiency for the simple reason that an abundant fuel supply is not conducive to such a development.

During the past few years, a tightening up in the gasoline supply has become apparent, and despite various expedients for maintaining the gasoline of earlier days, a notable change in quality has come into evidence. Gasoline has been getting heavier, less volatile, embracing an increasing quantity of material formerly produced as kerosene. This progressive change in gasoline quality is especially noticeable in winter, because of difficulties in starting engines, and it has also led to the dilution of the crank-case oil with resulting losses in power, smoothness, and life of the machine. So long as both fuel and engine remained standardized, all was well. Now the fuel is undergoing de-standardization, so to speak, and the engine, built to use high-volatile gasoline, is forced to use low-volatile gasoline. Already the engine has recognized this maladjustment, as indicated by superficial concessions to this state of affairs,—pre-heaters, hot-spots, and the like,—and by the upgrowth of a host of so-called fuel-economy devices. The engine is passing through an era of superficial concessions to the fuel situation.

Unless the present trend of motor-fuel reverses itself, the automotive industry will have to cope with a fuel growing progressively less specialized or else with a diverging range of fuels which comes to the same effect. The automotive industry, theoretically, can stop the change now taking place in fuel by holding fast to the present engine in detail, but this procedure will so limit the supply and increase the price of fuel that in practice the engine will have to give way. It is concluded, therefore, that an era is arriving when the engine will have to make rather radical concessions to fuel, as a relief to a strained situation; and the problem before the automotive industry is, first, to recognize this situation, and, secondly, to establish means for making these concessions with the maximum easement to the supply and price of fuel. Anything short of this will mean just so much of a detriment to the growth of automotive transportation. A view of the rapidly increasing demand for motor fuel, as shown graphically in figure 33, with reference to the limitating factors in supply already noted, will emphasize the likelihood of conditions arising that will influence engine design.

The inevitable concern of the automotive industry in the motor-fuel situation is just coming to be appreciated. A few years ago it was rather generally felt that fuel was a thing apart from automotive manufacture. Now the fuel situation is a live issue in the automotive industry.

The rise of a fuel problem, however, was not entirely unanticipated. For years the United States Geological Survey and the United States Bureau of Mines have pointed out the limited size of the petroleum resource and the need for its conservation. In 1918, the Bureau of Oil Conservation of the Oil Division of the Fuel Administration made a special study of the motor-fuel situation and urged both upon the National Automobile Chamber of Commerce and the Society of Automotive Engineers that the matter be brought effectively to the attention of the automotive industry. At the Winter Meeting of the Society of Automotive Engineers on February 5, 1919, a morning was devoted to a fuel session, at which time a number of authoritative papers were presented, which served to outline the situation and call attention to the issue. Since this meeting there has been a general agitation of the matter, and the topic of motor fuel has come prominently before the automotive interests and the oil interests as well.

The problem raised by the limitations of the petroleum resource is unique. It involves the running out of one resource and the coming into play of supporting resources. The problem centers and focuses on the matter of motor fuel, since the automotive field is the largest activity dependent upon petroleum and at the same time is the first to be affected by the conditions of supply. The problem involves the necessity of making the remaining supply of oil go as far as possible as a source of motor fuel and of insuring the development of the most economical supplements. The problem, therefore, takes on a threefold aspect,—conservation of oil, to insure its fuller utilization; a tempered development of supplementary resources as fast as needed; and the coördination of engine development with the trend of fuel supply, to insure efficient utilization of the fuels provided as well as to enable the most economical fuels to be produced.

The problem will ultimately work itself out, under the give and take of competition, through the agency of an advancing price, which will dictate the three lines of action outlined above. Such a solution, however, will place motor fuel upon a higher price level and run the danger of creating a temporary period of fuel stress, with lack of adjustment between supply and demand. Since these results would prove unfavorable to the oil industry, the automotive industry, and the general public jointly—whose ultimate best interest is an unbroken advance in automatic transportation—a common understanding of the situation has the possibility of providing a more constructive solution.

In respect to the conservation of petroleum, the most conspicuous fault to be found with this substance is the manner in which it is produced. Owing to the prevalent system of highly competitive mining in areas divided into numerous, separately owned tracts, there is of necessity a hasty production of the oil that prevents an efficient extraction. The shortcomings on this score have been commented upon in Chapter IV. The most notable losses arising from this circumstance are involved in periods of overproduction, in underground diffusion of the oil because of the infiltration of water into the oil-bearing stratum, in the failure to make adequate use of the oil-lifting power of the associated natural gas, and in a generally undeveloped production technique which leaves a considerable portion of the oil underground when the field is abandoned as "exhausted." The remedy lies in two directions: the establishment and furtherance of coöperation among producers to decrease the harmful effects of competitive production and a gradual doing away with the present discordant system of production. The mining of oil in units smaller than those determined by the geological occurrence of oil is the prime cause of the trouble. Coöperation among producers can be fostered by a vigorous campaign such as is now being conducted, according to the means at its disposal, by the Bureau of Mines. A fundamental remedy, however, can only come as a result of an enlightened public opinion which will disfavor small holdings.

The development of supplements to gasoline calls for a clearing away of obstacles, rather than a definite program of direct action. Supplements may be expected to come into play under commercial stimulus, as soon as needed, if not held back by artificial factors. For example, kerosene and fuel oil are not now available as satisfactory motor fuels, because engines have not been adapted to use them; benzol is available in limited quantities only, because this country is exceedingly backward in the proper utilization of coal; alcohol is handicapped by a legal environment which has not yet recognized its potentialities. The situation needs to be cleared so that there can be a free-for-all start, to the end that developments may follow the most economical lines.

The upgrowth of supplementary fuels involves also the most intricate aspect of the entire problem, the coördination of engine and fuel. The difficulty here is that both fuel and engines have various possible directions of development. Under present conditions the two come into adjustment by a process of trial and error. This process worked fairly well so long as fuel was virtually constant in character. From now on, however, fuel will likewise be a variable, and the matter of adjustment will be much more complex, —so much so, indeed, that the system of trial and error will ultimately be succeeded by a system of scientific planning and control. The paramount problem, therefore, is to insure, so far as possible, a parallel and complementary development of fuel and engine. This attainment is dependent, in part, upon the degree to which the mutuality of interest as between the fuel-producing industries and the engine-building activities is recognized and turned to use as a motive for coördination;

in part, upon the degree to which the Government interests itself in the matter.

In addition to the results that may be attained through conservation, development of supplemental fuels, and adaptations of the engine development to a changing fuel supply, there is need for a steady progress on the part of the engine toward greater thermal efficiency, which means greater economy in fuel, more miles to the gallon. The average automobile is notably wasteful in its use of fuel, and the fuel supply may see its service doubled without an increase in volume, once fuel economy becomes a paramount issue in engine design.

The motor-fuel problem is not one which laboratory research alone can solve. The fuel situation must be explored and harmonious fuel policies must be developed, in addition to the work of research upon fuels and engines. A fuel-betterment effort, therefore, to be adequate, must accommodate three functions,—economic analysis, to determine the course of fuel developments in relation to engine design; research, to build up the technology requisite to advance in fuel efficiency and fuel production; and industrial coördination, to insure an aggregate of fuel policies in adjustment with the needs of the fuel situation.

It cannot be emphasized too strongly that an ample supply of fuel depends not only upon the efficiency obtained in the engine from the fuel actually used, but also upon the efficiency attained in the realm of fuel production, which is contingent, in part, upon the requirements of the engine type. It is the peculiar nature of the fuel problem to embrace the possibility of contributing to an easement of fuel supply in these two directions.

In fine, then, the problem raised by the passing of petroleum is just beginning to be felt under the head of motor-fuel. Once it becomes generally known that the future of automotive transportation is at stake, this matter will doubtless receive the measure of attention it deserves.

CHAPTER X

THE EQUALIZATION OF INDUSTRIAL OPPORTUNITY

POWER and raw materials constitute the basis of industry. Capital, labor, markets, and other elements enter into the structure, but they do not lie at the base. Neither power resources nor raw materials are uniformly available; both tend to be provincial in occurrence; but as industrial power is dominantly drawn from coal, while raw materials are derived from a thousand sources of organic and mineral origin, the aggregate availability is far more restricted in the case of coal. In other words, any given section of the country is almost invariably provided with raw material of some kind, while under present conditions of power supply only those sections contiguous to rich coal-fields are amply provided with power. The geographical and political consequences of the localized occurrence of coal and of concentrated types of raw material are obvious and well known. The inequalities of opportunity conditioned by these matters have always been bones of contention, from the aboriginal strife over deposits of salt and flint down to the competition for the European deposits of coal and iron which played such an important part in the World War and the territorial adjustments following.

Discord of such origin is as old as human history and nations have evolved with the placement of their boundaries strongly influenced by concentrations of resource opportunity. The North American Continent, however, provides a notable exception to the rule. Its vast area was explored and appropriated before its resources potentialities were recognized, and its various sections came to be unified into a few nationalities on the strength of social bonds, which, with one or two exceptions, have nowhere been dissevered by subsequent economic influences. The United States is a nation of many parts bound together by social unity but separated by a divergence of economic interests. The development of natural resources has given rise to a marked differentiation in the quality of opportunity opening up to the different sections, while the boundaries of the economic provinces set up in this wise are further emphasized by a general conformity to topographic features disfavoring intercommunication.

Thus this country is displaying a steady drift toward economic variation and specialization among its members.

But national well-being is dependent upon economic unity no less than upon social unity. The Civil War, in the last analysis, had its origin in discordant economic sectionalism. A military expression of domestic discord is outgrown, but civil strife is not the sole misfortune that may arise from cross interests. Without economic unity a definite economic policy is nationally unattainable And with no formulated economic policy, one of the two prime functions of government is reduced to the rank of partnership, and industry is left to the paralyzing influence of uncertainty as regards the future of its operations. So far the divergent economic interests of the various sections of the country have not permitted the establishment of a constructive economic policy satisfactory to the nation as a whole.

Elements too numerous to specify enter into this sectionalism of interest, but the most conspicuous contributor is the presence or absence of resources productive of mechanical energy. Given a region endowed with an ample supply of coal, for example, and all the other elements of industrial activity gather in the manner of an accretionary growth. Even the crudest raw materials tend to be drawn to the sources of energy in greater measure than is found true of the reverse relation. Other attractions, to be sure, such as labor supply, markets, and transportation facilities register strong claims tending to diffuse and spread the focus of development, but industrial concentration never migrates beyond the convenient reach of power, which therefore sets the outside bounds to industrial range. Thus certain naturally favored sections of the country have come to have a predominant interest in manufacture, while other sections in the rôle of producers and consumers for the manufacturing areas are led to react to motives and economic interests foreign and even antagonistic to those of manufacture. Where such a situation is permitted to develop in accentuated form, an economic policy satisfactory to the two extremes would appear to involve a type of concord foreign to human nature.

The influence of energy resources in an unfavorable and favorable direction may be illustrated by two examples; one drawn from conditions obtaining in New England, and the other taken from recent industrial developments in the South Atlantic States.

In New England the foundations of industrialism were laid during the régime of water-power. With the advent of steam-power the abundance of coal available to the Middle Atlantic States set up a strong counter attraction which entailed a steady migration of industry away from the New England section. The counter attraction was especially potent, as New England contains no coal itself, and is marked by physiographic conditions which provide inadequate gateways for rail transportation, thus necessitating a roundabout rail-to-water-to-rail service exposed to all manner of exigency. The weakness of New England in this respect was very conspicuously evidenced during the war. Still, with the advantages of its early start, New England maintained a powerful asset in the form of skilled labor, and the weight of this factor has overbalanced the lack of an adequate power supply in those special forms of industry involving specialized workmanship. These, therefore, still prevail and reflect the peculiar color of the situation. But in the newer industrial sections elsewhere skill of workmanship is in process of development, and is steadily lessening the attraction of an advantage which transiently favors New England. In time this factor will be virtually neutralized, and with continued inequality of power supply New England will see its industrial life narrowing under the cumulative weight of a growing handicap. This is an example, then, of how a natural power supply may create a development in one part of the country at the expense of another section, a circumstance not making for unity of interest.

The South Atlantic area resembles New England in respect to power resources; coal must be hauled in from a distance and water-power is fairly abundant. But whereas the industrialism of New England is the oldest in the country, that of the South is among the youngest. Here, indeed, the growth of industry has been largely a matter of the past twenty or twenty-five years,—subsequent, therefore, to the introduction of electricity as a motive force. In consequence much of the upgrowth is built upon the use of hydro-electric power, and tends to be distributive—that is to say, *natural*—instead of a forced growth in proximity to localized coal belts. Coming into action late, the industrialism of the South, unhampered by tradition and unencumbered by obsolescent power establishments, took over the practice best suited to its needs. Thus while the northeastern States form an illustration of centralized industry, establishing itself first in New England and migrating later to the Central Atlantic States and thence westward, the South displays a regional deployment of industry, nowhere intensely focused, but spread, on the contrary, in diluted form over a large area. The contrast is suggestive; for permanence, for national well-being, for the common good, it would appear that a balanced economic life in which each section manufactures, in large measure, its own products is preferable to a highly intensified manufacture setting up its own interests in opposition to the more extensive producing areas. The South presents an example of power supply disposed to create a normal development from within, with minimum detraction from the opportunities peculiar to other sections.

These are but two illustrations of fields in which power supply is a strong economic force. Each section of the country, in point of fact, has its own peculiar reflex to this matter. The Pacific coast, for instance, has a specialized and acute power problem; the rich oil-fields of California launched a period of industrialism which this source of power cannot much longer sustain. The industrial life of this whole section is threatened by the impending decline of its oil-fields. Similarly with the Southwest. The power influence, then, is country-wide,—here throttling established industry; there leading to overbalanced growth; elsewhere retarding needed developments; rarely promoting well-rounded economic growth; on the whole making for divergence of economic interest.

This situation, undesirable as it stands, is bound to grow worse if matters are left to untrammeled evolution. Human labor is mobile; it is becoming standardized, even nationalized; cheap labor locally restricted is disappearing. Thus the factor of labor supply is losing its distributive effect upon industry. In consequence, the presence of mechanical labor (power) will become an even greater centralizing force than heretofore; manufacturing districts will tend to be more strikingly developed than ever. The natural tendency, in short, will be toward the building up of centralized industry enjoying monopolistic advantages of power supply, a condition in itself constituting a restraint in respect to the adequate unfoldment of other industries beyond the reach of the favored source.

Such an interplay of economic forces is complex and proclivities cannot be expected to travel far undeflected by new conditions, but whatever the uncertainties of the matter, the power situation merits attention in respect to its present untoward bearing on economic policy. If a constructive economic policy is desirable for this country, and if the conclusion is valid that the power supply represents a force now working against the unification of economic purpose into a national policy, but capable of direction toward such an outcome, the whole matter becomes a fundamental issue which may not be ignored. In short, a coördinated and balanced development of the coal and water-power resources of the country will serve to equalize industrial opportunity and therefore to unify the economic interests of the country so that a constructive economic policy agreeable to all sections may win country-wide support.

But in addition to its bearing upon national policy, a distribution of power advantages will make for an indirect but very significant gain in the matter of transportation; for industry may then strike a more perfect balance between the location of raw-material sources and markets. As the matter now stands, the adjustment is a compromise among three main factors, of which the position of the fuel source is dominant; and the industrial centralization resulting is in considerable measure responsible for the "bottle-neck" restrictions in the transportation layout of this country,—a pattern that has become a conspicuous source of transportation weakness during the past few years. The nationalization of industrial opportunity through equalized power supply will permit the upgrowth of new industrial activities in positions which will impose a lessened relative burden upon the railways and diffuse the intensification of responsibility now bearing with growing force upon the neck-like restrictions in the neighborhood of present industrial centers.

Thus the power supply, as it now stands, constitutes a strong attractive force, leading to marked industrial concentrations in certain parts of the country. The unfavorable bearing of this circumstance upon the attainment of a national economic policy is noteworthy and constitutes an argument for directing the sectionalizing force of power supply into more distributive channels than it seeks of its own accord. The most effective means toward a better balanced industrial growth in this respect is afforded by electricity, which lends itself to generation at fixed points in coal regions and at water-power sites, and to transmission thence to adjacent areas in such manner that, if the growth as a whole be properly shaped, a much larger portion of the country may be served with power on terms of equality than is now the case. Thus can power be turned away, in considerable measure, from its present dangerous facility in accentuating diversity of economic interest and made to contribute to the nationalization of industrial opportunity.

But just as coal contains valuable commodities as well as stored-up energy, so electricity is not merely a convenient form of power but is a new and profoundly important chemical agent as well. In this sense electricity represents a fresh industrial factor which is just beginning to come into play and bids fair to make for itself a master range of activity. Electricity, then, is not only capable of distributing industrial opportunity; it is competent at the same time infinitely to enlarge the scope of industrialism. The opportunity in this direction is so significant and has so recently become apparent that the field merits a close view in connection with the whole matter of power supply.

This field of special electrical service, in contradistinction to the application of electric energy as a motive force, is covered by the term "electrochemistry," which is the art of applying electrical energy to the furtherance of chemical operations. (See figure 37.) The aptness of electricity for this purpose has proved so great that in scarcely more than a decade there has developed a large number of electrochemical industries,

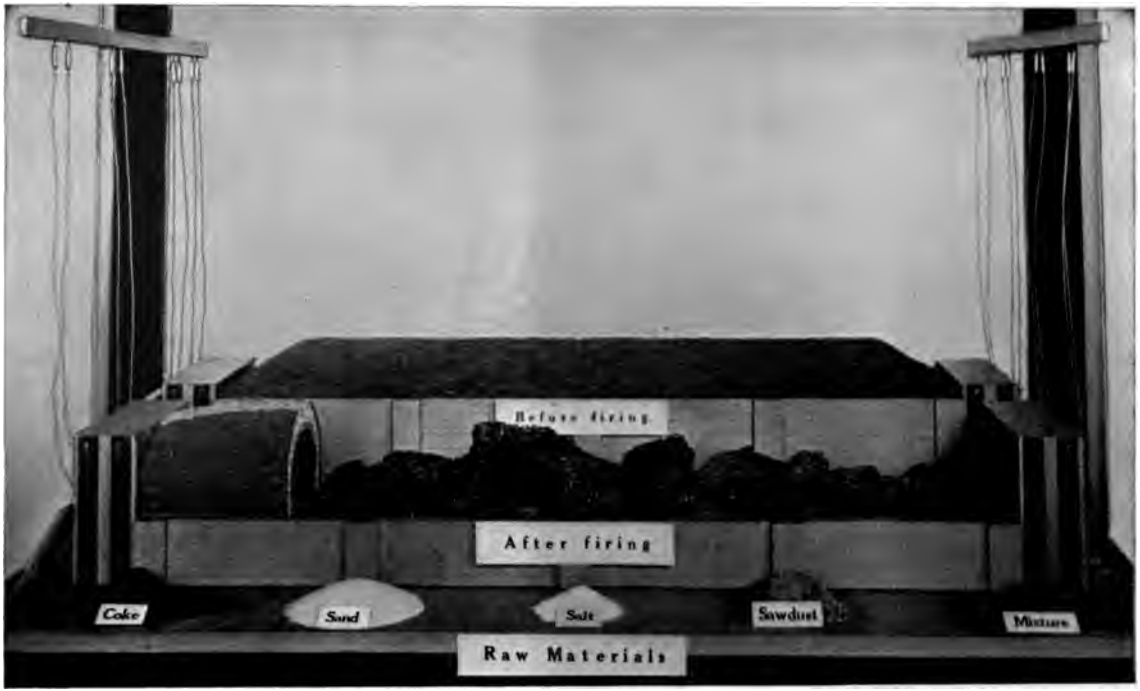


FIG. 37. An electrochemica industry: the manufacture of carborundum, a synthetic abrasive. (From model in the Division of Mineral Technology, U. S. National Museum.)

in addition to a growing range of superior adaptations in established industries and in the realm of metallurgy, with the setting up of a new branch of the latter known as electrometallurgy. Thus electrochemistry has not only facilitated ordinary industrial activities in many directions; it has opened an unbounded territory never before traversed by industry.

The facility of electricity in this new realm is due to its capacity for generating heat under conditions open to exact control, over high temperatures not attainable by fuel combustion, and in absence of gases, together with the exertion of a chemical force of decomposition independently or in conjunction with the heating effect. Thus electrochemistry operates through its dissociating effect upon solutions and melts, a process technically called "electrolysis"; through discharges in gases; and by means of electric furnaces. Upon these operations depend the manufacture of alkalis, chlorine, atmospheric nitrogen, graphite, artificial abrasives, and calcium carbide; the production of aluminum and many of the steel-hardening metals; and the refining of gold, silver, and copper,—to mention merely the most conspicuous attainments of the electrochemical art.

The achievements of electrochemistry to date are to be credited mainly to the region around Niagara Falls and to foreign countries, especially the latter. Elsewhere in the United States there are relatively few electrochemical activities. Such as have been established are in the vicinity of choice water-power sites or, as in the case of recent atmospheric nitrogen fixation plants, subsidized by the Government. But, by and large, electrochemical industries are grossly undeveloped in this country, relative both to their intrinsic importance and to their upgrowth abroad; and while a considerable expansion resulted under the stimulus of war prices, the course of progress is under the handicap of power costs running far in excess of what is offered in Canada and abroad. As power is a large item of expense in most electrochemical activities, its high cost in the United States is not only preventing development, except along specialized lines of high-value small-bulk products, but is causing an emigration of such industries to other countries offering a more genial atmosphere of power costs. Not only this but the tide of emigration is actually affecting the industries already established at Niagara Falls. On the whole, then, our electrochemical industries, while growing in an absolute sense, are relatively stationary, if not actually retrograding. That is to say, our electrochemical needs are growing faster than our electrochemical industries, which means that an increasing dependence upon foreign developments is under way.

In the realm of metallurgy, electricity opens to use a number of metals not commercially extractable from their ores on any other terms. The most conspicuous example is aluminum, which was a chemical curiosity until thus made available; but such metals and elements as magnesium, calcium, sodium, potassium, cerium, and silicon are also coming into prominence, although the application of these newer additions are still in their infancy. It is not unworthy of note, although the bearing of the fact may not become conspicuous for many years, that electrometallurgy offers a means for turning the more common and leaner mineral materials to account when the exhaustion of the rather limited and rich concentrations heretofore exploited shall have been accomplished. In this connection it may be recalled that the valuable elements available solely by electrochemical means constitute nearly half of the earth's crust, while such useful elements as copper, lead, zinc, nickel, tin, and the like, available before the advent of electricity, comprise together less than 1 per cent.

For the manufacture of a great number of metallurgical alloys, such as ferromanganese, ferrochromium, ferrotungsten, and others needed to give to steel the various special properties demanded by its many applications, electric power is essential, while for the production of iron and steel the use of electricity is finding a growing application. Indeed, many "metallurgists in active practice in the United States are convinced that the time is rapidly approaching when all steel made will be passed through the electric furnace to receive its final refining and its finishing touches. We may safely look forward to the establishment of not only hundreds but possibly thousands of electric steel furnaces." In the metallurgy of copper, zinc, and tin electricity is coming into play, while in the refining of metals it is affording the means for recovering many constituents formerly going to waste, in addition to producing products of such purity as to open up new uses not previously enjoyed. The United States is the greatest producer of metals in the world, and proper electrical-power development will give a great impetus to the advancement of the mineral industries.

No problem is more fundamental to any country than the matter of food supply, and electrochemistry has a very direct bearing in this respect through its promise of lending assistance in producing fertilizers. Of the three important fertilizing elements—nitrogen, phosphorus, and potassium—nitrogen may be drawn from the atmosphere by the expenditure of electrical energy; cheap electrical power offers an immediate means for doing away with the cumbersome method of converting phosphate rock into acid phosphate, with its consequent burden upon transportation and upon sulphuric acid manufacture; while the locked-up stores of potash held in unlimited amount in wide-spread areas of silicate rocks must eventually be drawn upon and presumably with the help of electric current. It is scarcely too much to say that the fertilizer industry in the course of a decade or so will undergo a marked change, in which importations of Chilean nitrate, German potash, and Spanish pyrite will be a thing of the past. But the course of progress will depend very much upon the conditions surrounding the supply of electrical power in this country; this matter will determine the speed of advancement and reflect in some measure upon the cost of living.

In the field of manufacturing, electrochemistry occupies a unique place. It has already created a number of products of fundamental usefulness, while the latent opportunities for the future are very great. The development of artificial abrasives, especially carborundum, superior to natural abrasives, has greatly facilitated many processes of mechanical manufacture, such as the making of automobiles, ordnance, and other materials; the production of calcium carbide has made the acetylene lamp possible, with inestimable benefit to thousands of mines the world over, which have thus been freed from smoky oil lamps and flickering candles; and the manufacture of artificial graphite is rendering a useful service as a lubricant in conserving energy. These products, which are of much greater significance than may be measured by the pecuniary value of the output, have been developed at Niagara Falls as a result of the abundant electric power available there and are made from raw materials of the commonest and cheapest kinds, such as sand, lime, coke, and others. Further products, too numerous to specify, are being commercially launched or are in the experimental stage in the works and laboratories of that electrochemical center. An important industry has also developed in the electrolytic manufacture of sodium and chlorine, and their numerous compounds, used in large quantities in a wide variety of other industries, which are made from common salt,—a widespread and cheap material. It would appear that one striking characteristic of electrochemistry is its ability to convert into useful products the commonest and cheapest of everyday materials. It holds forth in this sense the prospect of the highest type of constructive economic service.

On the whole, then, electrochemical activities have developed in the United States to some extent despite high electric-power rates, but the lines of development have been those in which the advantages to be gained were conspicuous and the operations have been largely confined to Niagara Falls. In the vaster range of possibilities, in which the opportunities were not so outstanding, high rates and lack of available power have been sufficient to head off an incalculable range of prospective enterprises, to the country's serious economic loss.

The whole field of electrochemical development in the United States is dependent in the last analysis upon the quantity and price of electric power. And in both respects the power situation as it now stands is inadequate. Unless we are prepared to see the electrochemical industries which we now have emigrate in part to foreign countries, and unless we are also willing to face a stagnant condition in respect to a wide range of important industrial developments, the whole matter of our power supply must come up for attention.

CHAPTER XI

COÖRDINATION AND INDUSTRIAL EVOLUTION

THE goal of society is human welfare and progress toward this end is limited by economic competency. There has always been an intimate interplay between social and economic status, and the problem before the world to-day is to coördinate the social and economic aspects of existence so that the world-wide advancement in social consciousness may be sustained by a supporting adjustment in economics.

The dominant economic factor underlying social advance is the increase in production arising from the substitution of mechanical work for human labor. The means for conserving and more fully utilizing human energy has come into commanding importance with the discovery of steam and electricity, and has resulted in a growing utilization of the energy resources, coal, oil, natural gas, and water-power. To a degree difficult to appreciate fully, modern civilization is dependent upon the work performed by resource energy.

The upgrowth of industrial civilization has led to a tremendous focus upon the details of energy application, but little attention has been paid to providing the energy efficiently or to directing the energy to its maximum social advantage. The means for using energy, in consequence, have multiplied and ramified until they have overrun the whole body of society, while the sources from which the energy is drawn and the social ends to which it is applicable have been lost sight of almost entirely. Because of this discordant development, the material basis of our modern civilization has come to be badly out of adjustment with the entire social and economic structure resting upon it.

The faults arising on this score are among the most serious to be found in our social and economic fabric to-day. We are involved in a wasteful and careless exploitation of our energy resources, which is rushing upon us a premature depletion of our richest sources of supply and creating imminent problems in industrial readjustments of far-reaching significance. We have permitted, unchecked, the development of harmful concentrations of industrial activities in limited areas favored with fuel, to the creation and aggravation of labor problems that seem insolvable. We have seen our transportation system staggering beneath the sheer bulk of energy haulage, with a recent breakdown in operation which clearly indicates the incapacity to function in periods of industrial expansion. And despite our already notable use of mechanical energy, we have a labor problem growing constantly more acute because of our failure to administer adequately the forces of mechanical labor.

These defects in national structure represent points of weakness where the strain is greatest. They already invite attention through the warning sounds of social unrest which are heard on every side. Danger arises not so much from an ignorance of the symptoms as from a failure to diagnose their origin. As a nation we have failed to diagnose their origin. As a nation we have failed to sense that the inadequate development of our energy resources is responsible for a large measure of the social shortcomings that are present in our economic situation.

The war served to aggravate these matters and bring them to a head. As a result of this social revolution, social consciousness the world over has been stimulated and increased. An insistent demand for a permanent advancement in the standards of living has thus been created, at the same time that the productivity of the world has been impaired through its enforced attention to the affairs of destruction. Faced by an actual shortage of materials and a social consciousness on the part of the masses which will not complacently accept a reduction in the standard of living, we must greatly increase the productivity of our industrial processes so as to meet their needs, or else look forward to a continuance of industrial chaos and unrest.

The whole situation comes to a focus in the universal disaffection over the cost of living. The advance in social consciousness, so accentuated by the war, has been accompanied by a corresponding increase in the cost of production. The demands for increased human compensation have been met, but the increments have been added to the price of commodities. Hence the opportunity for a growing social consciousness to express itself in an advancing standard of living has been nullified by a parallel advance in costs; the result is a public opinion at odds with the outcome and a governmental response in the form of hurried attempts to quell the storm by palliative measures.

To remedy the situation, we must find an economic support for the advance in social consciousness, and the only real support in sight is through the medium of a more conserving industrialism. If we analyze the matter of cost in industrial processes, we find that the chief item is motion, represented in human labor, mechanical work, and transportation, the ultimate cost of materials as such being a minor part of the total. Hence the cost of motion is the chief element in the cost of living which bears down so heavily upon all society. To reduce the cost of living, therefore, will necessitate a reduction in the cost of motion. Analyzing the matter still further, we observe that motion is composed of legitimate and waste, or lost motion. The problem of reducing the cost of living, therefore, narrows itself fundamentally to the elimination of lost motion; and since motion results from the expenditure of energy and the energy situation is notorious for its lost motion, the most potent means for relief in sight lies in a coördinated and efficient administering of resource energy.

Upon our attention to energy, the future of our democracy depends. The most critical point in our whole structure is the social unrest arising from the advanced cost of living, and this is due, in the last analysis, to the fact that the most important factor toward reducing cost has not been applied to that purpose. What is needed is a wide-spread appreciation of the significance of energy as a factor in living cost, which will bring a pressure of public demand that will lead to an adequate method of energy administration.

The purpose of the foregoing chapters has been to draw attention to the shortcomings of the energy situation and to point the directions in which betterment may be effected. Once the true meaning of energy and the social faults for which its maladministration is responsible are incorporated in public consciousness, progress in the direction indicated may be expected. The problem at bottom is one of education.

In short, we stand in need of a coördinated development of our energy resources to support a sound economic and equitable social advance.

We need a system of production for our energy materials which will be in harmony with the geological occurrence of the resources, to eliminate the appalling waste of effort now taking place in their exploitation. Integration of operations will make this attainable.

We need a new method of transportation for our bulkiest energy material, coal, which will be in keeping with our form value needs, to the end that energy may be more equitably distributed, water-power adequately utilized, and the railways relieved of an unnecessary burden. The development of a common-carrier system of energy transmission lines will fill this want.

We need a revision in the methods of utilizing our energy materials, so as to insure a higher recovery of the energy content and a proper employment of the commodity values for the purpose of reducing the cost of energy. This result may be attained through a furtherance of the principle of multiple production, coupled with adequate attention to the efficiency of the appliances concerned in utilizing energy.

But more than attention to the component parts of the problem is necessary. A weaving together, a coördination, of the entire field is essential, if both industry and society are to be served, if both economic and social advance are to be gained.

There is no easy way to this goal. No single formula will suffice. No superficial expedients of shifting authority, whether to governmental operation, to other forms of nationalization, or to large industrial combinations, may be expected to yield adequate results, unless there is a fundamental change in attitude which will bring scientific control to the direction of the entire activity. The real need is for a revision in the basic economics of energy supply, not for a mere shifting of control from one set of hands to another.

Unfortunately the Government, which should set the lead in this matter, has failed to sense its responsibility. Such coördinated, centralized developments as have already come into evidence in this field represent the response of industry to the necessity for reducing lost motion. And far from meeting encouragement, these beginnings of economic competency, these necessary evolutionary developments, have actually been confronted with a spirit of blind antagonism on the part of the Government. In the face of these circumstances, therefore, it would appear that progress in the future will come not so much as a result of governmental initiative in reshaping the established order, as through adjustments that industry itself will make under the stimulus of enlightened public opinion and advancing social consciousness.

This country has been devoting a great deal of effort to the need for Americanization and the future of democracy. The adequate employment of our energy resources—the provision of cheap, plentiful, and well-distributed energy—may be commended in the face of social derangement as the most potent influence toward Americanization and human welfare anywhere to be found to-day.

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